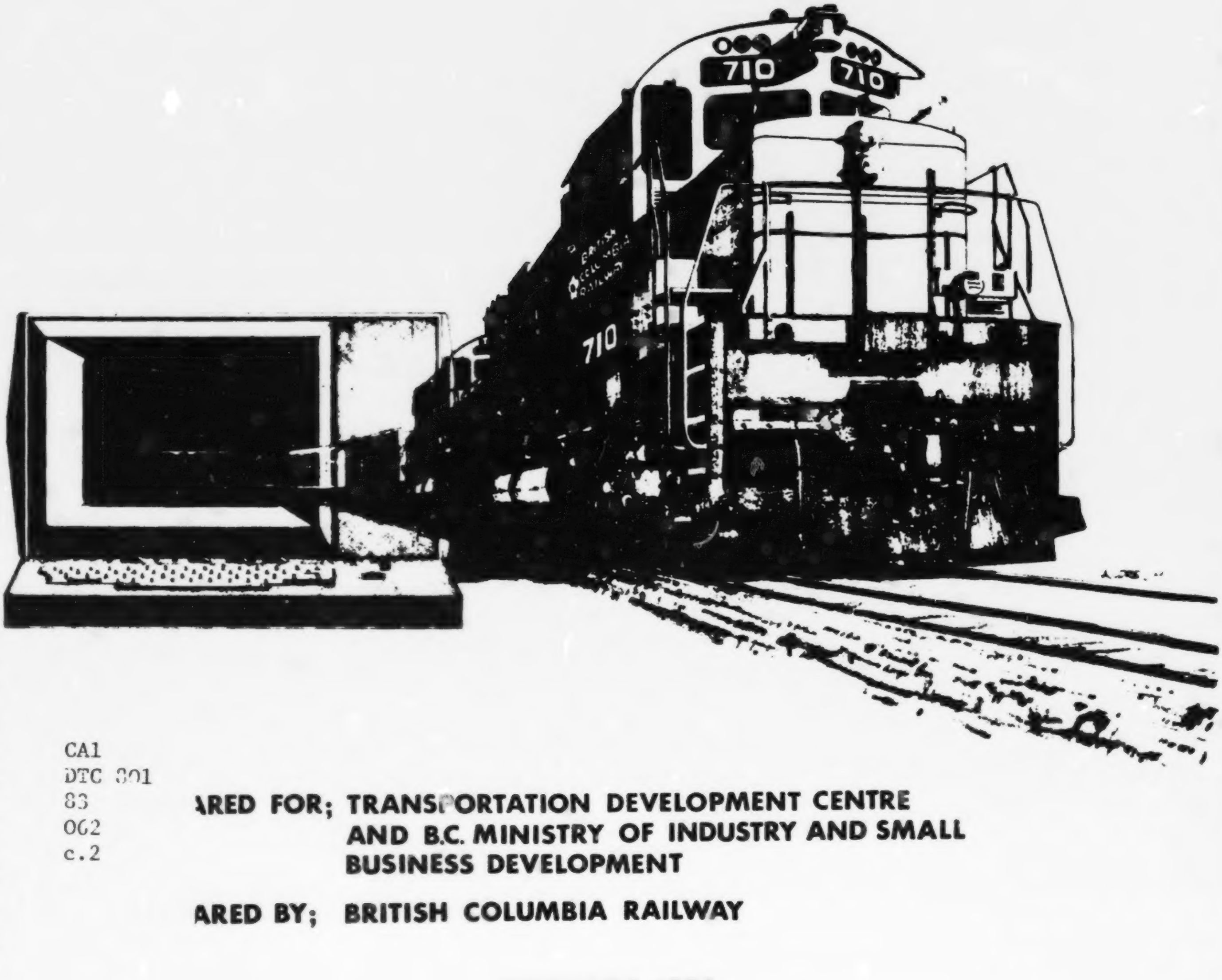
TP 4451

OPERATIONAL EVALUATION
OF
TRAIN TRACKING
AND
DISPATCHER ASSIST FUNCTIONS

LOCATION IDENTIFICATION AND CONTROL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Transportation Development Centre
And B.C. Ministry of Industry And Small
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PREPARED BY;

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17 Abstract

This report describes and evaluates the Train Tracking and Dispatcher Assist functions of the operational LIC System installed on B.C. Railway's Squamish Subdivision. The Location, Identification and Control (LIC) system is a computer-based block control system for railway traffic management. The initial test phase involved 6 LIC-equipped units and a single Data Collection Processor (DCP) as the central computer. As a result of the tests, modifications were made in several areas and the DCP was redesigned.

The second test phase involved 26 LIC-equipped units. A HOST mini-computer was added to the central computer system to manage the dispatcher assist functions. LIC functions were found to meet tracking requirements in all areas except odometer calibration. With the implementation of defined changes, it is expected that odometer calibration will meet specification. The transponder reporting rate was 99.86% overall. The communications success rate was 71.7%, but coverage is still poor in some locations. The dispatcher interface was tested and found acceptable. It is recommended that communications be upgraded and that the project proceed with implementation and evaluation of train control.

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17 Resume

Ce rapport décrit et évalue les fonctions de surveillance et de régulation du système LIC que B.C. Rail a installé dans sa subdivision de Squamish. Il s'agit d'un système informatisé de cantonnement et de régulation du trafic ferroviaire assurant la localisation, l'identification et la commande automatique de ces trains. La phase I des travaux d'essai a fait appel à 6 trains équipés du système LIC et à un seul processeur de données agissant comme unité centrale de traitement. Suite à ces essais, de nombreuses modifications ont été apportées et le processeur a été réétudié.

La phase II des travaux a fait appel à 26 trains équipés de ce système. Un mini-ordinateur HOST a été ajouté à l'unité centrale de traitement pour prendre en charge la fonction de régulation. Le système LIC a pu répondre à toutes les exigences formulées sauf celles touchant l'étalonnage de l'odomètre. Celle-ci pourra être satisfaite une fois que les modifications précisées dans le rapport auront été apportées. Le taux de réponse du transpondeur a été de 99,86 pour cent. Les communications ont été réussies à 71,7 pour cent, montrant ainsi les lacunes observées à certains endroits. Le rapport recommande d'améliorer les communications et de passer au stade de la mise en oeuvre et de l'évaluation de la fonction régulation.

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Your on-going support and dedication has had an inspirational effect on the development team.

EXECUTIVE SUMMARY

1. Background

British Columbia Railway currently uses two systems of train control: train order and manual block. Both methods depend upon voice and written communication between the train dispatcher, operators, and train crew.

In 1971, B.C. Railway began investigation of an alternative system of control based on train-mounted electronics and radio communications. Initial tests demonstrated the concept's feasibility, and in 1975 Transportation Development Centre provided funds for the development of a prototype LIC System on the Railway's Squamish Subdivision. Field tests of the prototype LIC System were completed in late 1978. The results demonstrated that LIC had the potential to be an effective means of train dispatching, but that improvement was necessary in several areas.

Early in 1979, B.C. Railway was awarded a contract to install an operational LIC System on the Squamish Subdivision. Prior to the development of a system specification, B.C. Railway reviewed the basic concepts of LIC operation. Dynamic or moving block control of train movement, as used in the prototype system, was discarded in favour of fixed blocks delimited by control points (CP's). Control points are located at each main track switch and at other selected points and are marked by two or more transponders as well as control point signs. A train requires specific authority, indicated on a locomotive cab display, to cross each control point. Routing, including the choice of track taken at switches, is established by a sequence of such authorities.

Glenayre Electronics was the prime sub-contractor for specialized hardware and software for LIC. On the basis of the earlier results, Glenayre carried out several modifications to the on-train equipment and to the central computer system. The latter involved the design and construction of a Data Collection Processor (DCP) to remove some of the processing load from the main computer, now designated the HOST Processor.

2. Objectives

The overall objectives of the LIC project are to:

1. Establish performance requirements, operating rules and technical specifications for an operational LIC System.
2. Complete development of all LICS hardware and software.
3. Install the equipment necessary to monitor and control all train movements throughout the full 154-mile length of the B.C. Railway Squamish Subdivision.
4. Operate the Squamish Subdivision under LIC control without train order dispatching for a continuous 24-hour per day period of three (3) months.
5. Establish, by means of direct operating experience and actual performance data, the safety and reliability of LIC for single-track train control in Canada.

The project is funded by the Transportation Development Centre, the Government of British Columbia, and B.C. Railway.

3. Basic Tracking

Three freight engines and three cabooses were equipped with pre-production LIC electronics and placed in normal operation. The central computer consisted of a single, stand-alone DCP. These units were monitored from October 2 to November 6, 1981, according to the Basic Tracking test plan. ("Tracking" refers to the process by which the central computer system maintains a record of the identity and current location of LIC-equipped units. Proper tracking performance is essential to the operation of the LIC System.) The Basic Tracking tests examined LIC performance in four areas:

1. Transponder Reporting: each unit was required to detect, identify, and report to the DCP at least 99.8% of all transponders crossed.

2. Odometer Calibration: each engine was to be calibrated initially at a transponder; the odometer reading at each subsequent transponder crossing was reported to the DCP and compared with the "known" transponder mileage.

3. Communications Coverage: for each unit, the DCP recorded the total number of transmissions it made and the total number of valid responses it received from the unit at approximately 5-mile intervals.

4. Train Location: on a dedicated printer, the DCP produced a time-distance graph showing the location of every equipped unit at 5-minute intervals.

The Basic Tracking tests led to the following results and conclusions:

1. The overall average transponder reporting rate was 96%, well below the minimum 99.8% required for proper tracking. Modifications were made to the ELU hardware and to the software transponder detection algorithm. With these changes it was decided to proceed to the next phase of testing, Full Tracking.

2. Engine odometer readings over a trip showed two important characteristics. First, there was a steady increase in the magnitude of the odometer error as the trip progressed, which indicated the need for an accurate correction factor to account for actual wheel diameter. The ELU software was subsequently modified to allow the measurement and application of such a wheel-wear factor. Second, plots of odometer error versus subdivision mileage showed a series of small but reproducible irregularities. From the consistency of these errors, it was determined that the chaining of the subdivision was incorrect in some places. The V-10 inspection vehicle made a series of trips over the territory with an accurately calibrated LIC odometer to measure the actual mileage of each transponder, and the DCP track model was updated accordingly.

3. The overall communications success rate (ratio of valid responses received by the DCP to transmissions made, averaged over all units and trips) was in the neighbourhood of 62%. This rate was considered adequate for tracking purposes, but fell short of the requirements for LIC Train Control. A plot of success rate versus location demonstrates clearly that certain areas, e.g., Cheakamus Canyon, have very poor communications coverage, while others are covered almost perfectly.

4. The DCP train graph proved entirely successful, giving a clear representation of both current and projected train location. On completion of the Basic Tracking tests modifications were carried out to rectify the problems encountered. In addition, it was determined that the current DCP design was inadequate for future needs. Consequently, the DCP hardware was completely redesigned and the software rewritten to provide much greater flexibility.

4. Full Tracking

The Full Tracking tests consisted of a full operational evaluation of production Engine Logic Units (ELU's) and other LIC equipment with a single HOST/DCP central computer configuration. The previous LIC-equipped units were retained, and a further 10 freight engines and 10 cabooses were furnished with LIC electronics. Additional units came into service in the course of the tests.

The Full Tracking tests were conducted according to Phase 4 of the LIC System acceptance test plan, and the test period ran from August, 1982, to January, 1983. The tests examined the four areas previously mentioned, with the following results:

1. Transponder Reporting: the mean rate of transponder reporting reached 99.86%, averaged over 5 samples of 10,000 operational transponder crossings. Various problems in both hardware and software were encountered and solved. Transponder reporting meets the specified rate of 99.8% or better.

2. Odometer Calibration: a full calibration procedure was introduced to measure and apply a wheel wear factor to odometer readings, but it was found difficult to stabilize the factor for a given unit. Low-speed performance of the locomotive axle generators was not acceptable for odometer purposes, and various modifications have been applied to correct the problem. A significant change was made in the ELU software to improve the accuracy of the odometer computations. It can not yet be confirmed that odometer calibration will meet specification, however, the problems involved do not affect implementation of LIC Train Control.

3. Communications Coverage: as the number of units in LIC service increased, the overall level of communications performance dropped drastically. Various problems were isolated and corrected, and the average performance level rose to 71.7%. This rate is considered to be adequate for train tracking. The specific areas of weak coverage still exist, and performance in these areas must improve before communications is acceptable for LIC Train Control.

4. Train Location: the DCP train graph and the HOST colour graphics display were both used in Full Tracking. The former performed to specification as it had on the original DCP; the latter is discussed below under Dispatcher Interface.

5. Dispatcher Interface

The LIC dispatcher interface was implemented on the HOST computer and was evaluated during the Full Tracking test period. The train dispatcher and chief dispatcher interact with the LIC System through the means of video display terminals, printers, and graphics displays. The dispatcher interface provides four functions outlined below:

1. LIC maintains an automated train sheet for every train in the system. The LIC train sheet contains data entered both manually (e.g., crew, consist) and by the computer (e.g., train performance). Dispatchers access the train sheet via a menu-driven sequence of video terminal displays. The automated train sheet performed according to specification except in the association and disassociation of active units (e.g., units already known to LIC) with dispatcher-created train sheets. This feature depends in part on a function which is part of LIC Train Control and is not yet implemented.

2. Colour Graphics Displays: three colour displays mounted above the train dispatcher's desk provide a scale representation of the LIC territory and all train activity therein. All control point and station locations are correctly displayed to a resolution of 1/4-mile. A LIC-equipped train is indicated by an arrowhead symbol pointing in the train's direction of travel and accompanied by an alphanumeric train identifier. It was specified that the arrowhead be maintained at all times within 0.5 mile of the train's actual location. This criterion was realized in Full Tracking, but it was found that it did not guarantee positive train location at control points as required by LIC Train Control. For this reason train location at control points will be based on transponder crossings, rather than odometer readings, in future implementations.

3. Dispatcher Displays and Reports: the dispatcher interface provides a wide range of data displays and printed reports, which may be selected via terminal menu. Certain displays contain data pertaining to a single train and are for immediate reference; they may be printed out as well. Others are summaries of information regarding all trains in the system. Finally, the system prints two reports automatically each day at midnight: a train sheet summary and a dispatcher duty log. B.C. Railway tested all of the displays and reports, and after certain changes it was concluded that this function met specification.

4. Shift Change Procedure: the system specification calls for a detailed procedure for dispatcher shift change. As LIC is not now used for actual train dispatching, the only parts of the procedure being followed are log on (with password) and log off, which allow access via the terminals.

6. Conclusions and Recommendations

LIC train tracking and dispatcher assist functions have been tested under operational conditions and have been found to meet specification for tracking purposes in all areas except odometer calibration. It is therefore recommended that the LIC project proceed with incorporation and evaluation of Train Control as described in the system functional specification.

Furthermore, the following detailed recommendations may be made:

1. The Railway should continue to test odometer calibration with specific regard to the procedure for full calibration. In addition, the Railway should make known to potential suppliers of the locomotive axle generator the particular requirements that have arisen from this study.

2. The Railway should continue to gather data concerning train location and the colour graphics display to determine a means to ensure positive train location at control points.

3. The Railway should continue to test the dispatcher interface with respect to the proper association and disassociation of units with train sheets.

B.C. RAILWAY ENTERS A NEW ERA OF TRAIN CONTROL. PREPARING LIC FOR PARALLEL OPERATION WITH THE EXISTING TRAIN ORDER SYSTEM.

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

Operational Evaluation of Train Tracking and Dispatcher Assist Functions

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1.0 INTRODUCTION

The Location, Identification, and Control (LIC) System is a computer-based block control system for railway traffic management.

LIC uses distributed intelligence and digital radio to monitor train movements and communicate control information from a central dispatching office. Processing equipment on the locomotive measures train speed and location and returns this information to the central computer. A plain-language cab display indicates operating authorities and other information for the engineman. Caboose equipment is used to verify that a train has cleared each block. The train dispatcher is provided with a colour graphics track display which shows train location, block assignment, and other pertinent information. In addition, the dispatcher has all data entry and report generation capabilities needed in the performance of his or her duties.

The LIC operating rules govern the movement of trains in LIC territory. The dispatcher's instructions are transmitted to the train under a highly secure radio communications protocol, and train information is returned to the central computer in the same manner. In certain cases, such as changes in operating authority, the engineman must actively acknowledge a directive before it may take effect.

The LIC System is intended as an alternative to train order or manual block control which increases the traffic capacity of the system at less cost than conventional track-circuit signalling. The precision of LIC's train speed and location information also make it attractive as an enhancement to centralized traffic control.

1.1 Background

In 1975 the Transportation Development Centre (TDC) funded a program to study the application of computer technology and radio communications to railroad train control. The objectives of the program were to design, implement, and prove the feasibility of an automated train dispatching system which involved on-train computer equipment linked by radio with a central dispatch office computer.

The system was based on electronic equipment and communications techniques previously developed and used to identify and track trains on the Squamish Subdivision of the British Columbia Railway. The earlier system had proved feasible the concept of intermittent determination of train location by means of electronic "mileposts" or transponders placed at intervals on the roadbed and reported to the dispatch office by train radio and microwave trunk.

The next logical step was to add a return link to carry train control information to the engineman. B.C. Railway and Glenayre Electronics entered into contracts with TDC to develop a full prototype Location, Identification, and Control (LIC) System. The prototype system employed a microprocessor in the locomotive to collect information, transmit and receive radio data messages, and display operating orders to the engineman.

Field tests of the system in 1977 established the feasibility of both the LIC System concept and the prototype hardware design.

The following conclusions were reached upon completion of the prototype test period:

1. The information provided by the System at the central office is sufficient for proper dispatching of trains.
2. Radio communications coverage on the Squamish Subdivision is adequate for operation of the LIC System.
3. An odometer derived from the locomotive axle pulse generator could be made sufficiently accurate for the purposes of displaying train location.
4. The on-train hardware was functionally adequate but required self-checking capability, a means to disable itself in the event of malfunction, and greater consideration of maintenance procedures in the final production design.
5. Polling and data collection produced high loading on the central computer at times, and the use of a "front-end" Data Collection Processor (DCP) should be considered.

This work is described in detail in TDC Document TP1993, "Train Location, Identification and Control Prototype System".

Early in 1979, B.C. Railway entered into the current contract to install an operational LIC System on the Squamish Subdivision (Figures 1-1 and 1-2). The contract work statements specified a sequence of defined tasks which were to be completed by the contracted party.

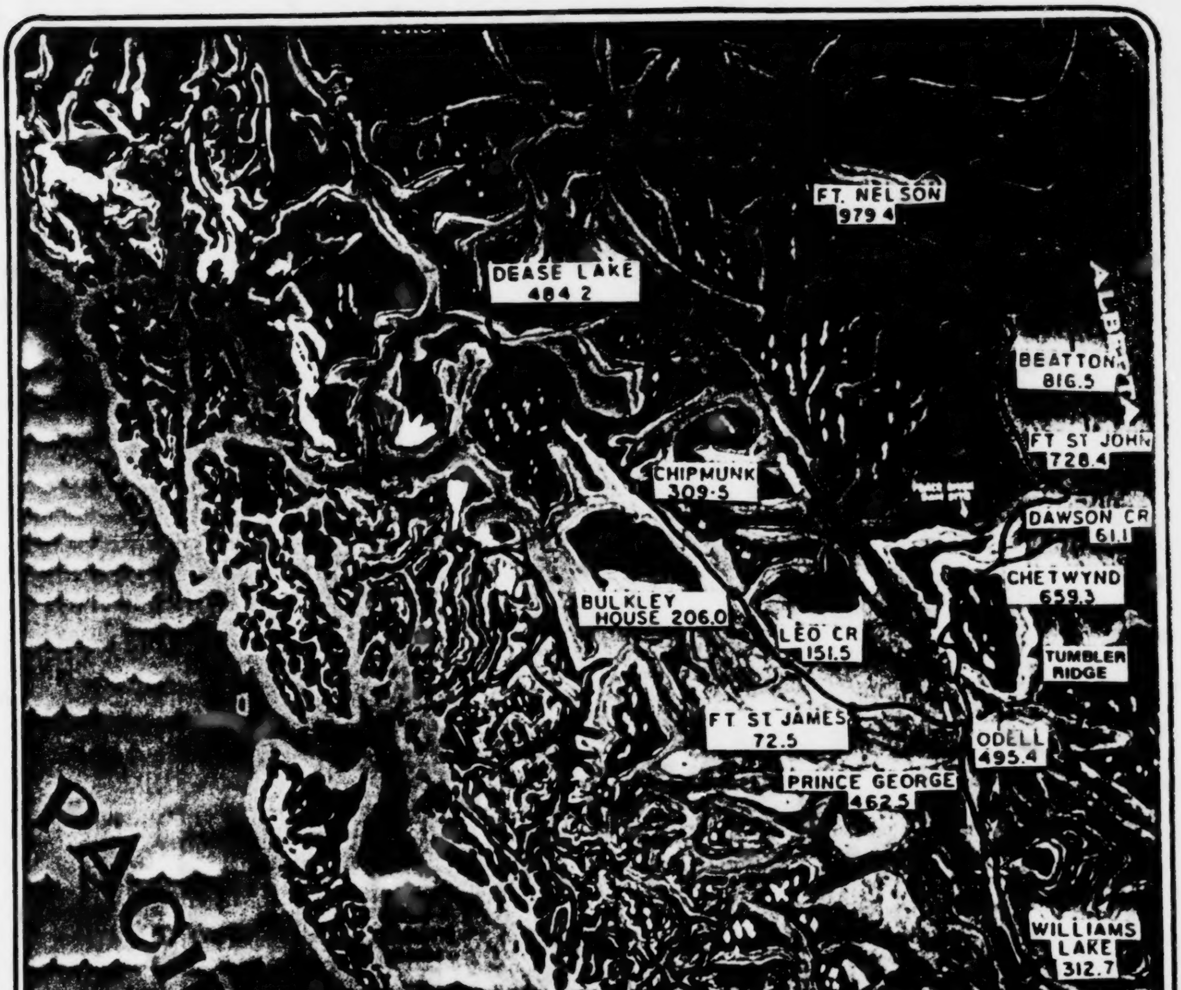
Work began on TASK 1, which comprised project planning, conceptual design, and preparation of the system functional specification. B.C. Railway's first action was to make a comprehensive review of the fundamental concepts underlying LIC operation. Train control in the LIC prototype was based on the concepts of a dynamic block and system-assigned speed limits. A six-mile engine-to-engine separation was maintained between following movements; meets between opposing trains were arranged as required. The engineman's control instructions consisted of speed limits and formatted train orders presented on the cab display.

As a result of the review of the prototype system, B.C. Railway decided upon a major conceptual change in train control from dynamic or moving block to fixed blocks delimited by identified control points (CP's). CP's are located at designated main track switches and at other selected points. LIC equipment sufficient to detect and report control point crossings was specified for installation in cabooses to indicate a train's departure from a block. Movement across any control point, including the required route at switches, is governed by explicit authority on the locomotive cab display. The display is continuously updated to show the current and next two authorities. Speed limits do not appear on the cab display but are indicated in the conventional manner by timetable, bulletin, or special instruction.

TASK 2 was concerned primarily with preparation of the Railway's physical plant and equipment for a LIC operational test. It comprised the following steps:

1. Installation of up to 100 additional transponders to complete coverage of the entire subdivision.

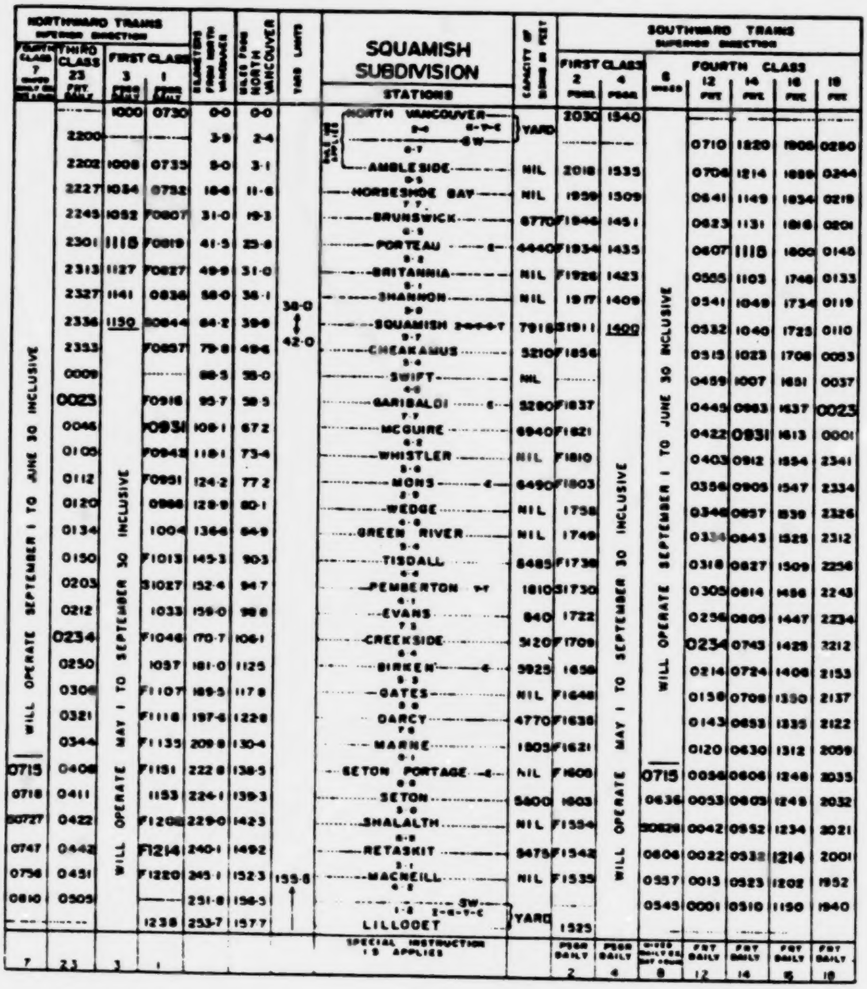
2. Installation of a second communications channel.


FT. NELSON 979.4
DEASE LAKE 484.2
ALBERTA
BEATTON 816.5
FT ST JOHN 728.4
CHIPMUNK 309.5
DAWSON CR 61.1
CHETWYND 659.3
BULKLEY HOUSE 206.0
LEO CR 151.5
TUMBLER RIDGE
FT ST JAMES 72.5
ODELL 495.4
PRINCE GEORGE 462.5
PACIF
WILLIAMS LAKE 312.7
LILLOOET 157.7
NORTH VANCOUVER
VANCOUVER

B.C. RAILWAY SYSTEM MAP

Figure 1-1

SQUAMISH SUBDIVISION STATIONS AND GRADE PROFILE
(EXCERPT FROM B.C. RAILWAY TIMETABLE #10)



NORTHWARD TRAINS SUPERIOR DIRECTION FOURTH CLASS 7 MIXED	THIRD CLASS 23 FRT DAILY	FIRST CLASS 3 PSGR DAILY	FIRST CLASS 1 PSGR DAILY	KILOMETRES FROM NORTH VANCOUVER	MILES FROM NORTH VANCOUVER	TIME LIMITS	SQUAMISH SUBDIVISION STATIONS	CAPACITY OF SIDING IN FEET	SOUTHWARD TRAINS SUPERIOR DIRECTION FIRST CLASS 2 PSGR	FIRST CLASS 4 PSGR	8 MIXED	FOURTH CLASS 12 FRT	FOURTH CLASS 14 FRT	FOURTH CLASS 16 FRT	FOURTH CLASS 18 FRT
WILL OPERATE SEPTEMBER 1 TO JUNE 30 INCLUSIVE	------	1000	0730	0·0	0·0		NORTH VANCOUVER	YARD	2030	1540	WILL OPERATE SEPTEMBER 1 TO JUNE 30 INCLUSIVE	------	------	------	------
	2200	------	------	3·9	2·4		2-4 8-7-C SW 0·7		------	------		0710	1220	1906	0250
	2202	1008	0735	5·0	3·1		AMBLESIDE 8·5	NIL	2018	1535		0706	1214	1859	0244
	2227	1034	0752	18·6	11·6		HORSESHOE BAY 7·7	NIL	1959	1509		0641	1149	1834	0219
	2245	1052	F0807	31·0	19·3		BRUNSWICK 6·5	6770	F1946	1451		0623	1131	1816	0201
	2301	1115	F0819	41·5	25·8		PORTEAU E 5·2	4440	F1934	1435		0607	1118	1800	0145
	2313	1127	F0827	49·9	31·0		BRITANNIA 5·1	NIL	F1926	1423		0555	1103	1746	0133
	2327	1141	0836	58·0	36·1		SHANNON 3·8	NIL	1917	1409		0541	1049	1734	0119
	2336	1150	S0844	64·2	39·9	38·0 ↕ 42·0	SQUAMISH 2-4-6-8-T 9·7	7916	S1911	1400		0532	1040	1725	0110
	2353	WILL OPERATE MAY 1 TO SEPTEMBER 30 INCLUSIVE	F0857	79·8	49·6		CHEAKAMUS 5·4	5210	F1856	WILL OPERATE MAY 1 TO SEPTEMBER 30 INCLUSIVE		0515	1023	1708	0053
	0009		------	88·5	55·0		SWIFT 4·5	NIL	------			0459	1007	1651	0037
	0023		F0916	95·7	59·5		GARIBALDI E 7·7	5280	F1837			0445	0953	1637	0023
	0046		F0931	108·1	67·2		MCGUIRE 6·2	6940	F1821			0422	0931	1613	0001
	0105		F0942	118·1	73·4		WHISTLER 3·8	NIL	F1810			0403	0912	1554	2341
	0112		F0951	124·2	77·2		MONS E 2·9	6490	F1803			0356	0905	1547	2334
	0120		0958	128·9	80·1		WEDGE 4·8	NIL	1758			0348	0857	1539	2326
	0134		1004	136·6	84·9		GREEN RIVER 5·4	NIL	1749			0334	0843	1525	2312
	0150		F1013	145·3	90·3		TISDALL 4·4	6485	F1738			0318	0827	1509	2256
	0203		S1027	152·4	94·7		PEMBERTON Y-T 4·1	1810	S1730			0305	0814	1456	2243
	0212		1033	159·0	98·8		EVANS 7·3	840	1722			0256	0805	1447	2234
	0234		F1046	170·7	106·1		CREEKSIDE 6·4	3120	F1709			0234	0743	1425	2212
	0250		1057	181·0	112·5		BIRKEN E 5·3	3925	1658			0214	0724	1406	2153
	0306		F1107	189·5	117·8		GATES 5·0	NIL	F1648			0158	0708	1350	2137
	0321		F1118	197·6	122·8		DARCY 7·6	4770	F1638			0143	0653	1335	2122
	0344		F1135	209·8	130·4		MARNE 8·1	1803	F1621			0120	0630	1312	2059
0715	0408		F1151	222·8	138·5		SETON PORTAGE E 0·8	NIL	F1606		0715	0056	0606	1248	2035
0718	0411		1153	224·1	139·3		SETON 3·0	5600	1603		0636	0053	0603	1245	2032
S0727	0422		F1208	229·0	142·3		SHALALTH 6·9	NIL	F1554		S0628	0042	0552	1234	2021
0747	0442		F1214	240·1	149·2		RETASKIT 3·1	9475	F1542		0606	0022	0532	1214	2001
0756	0451		F1220	245·1	152·3	155·8 ↑	MACNEILL 4·2	NIL	F1535		0557	0013	0523	1202	1952
0810	0505		------	251·8	156·5		SW		------		0545	0001	0510	1150	1940
------	------		1238	253·7	157·7		1·2 2-6-7-C LILLOOET	YARD	1525		------	------	------		
7	23	3	1				SPECIAL INSTRUCTION 13 APPLIES		PSGR DAILY 2	PSGR DAILY 4	MIXED 8	FRT DAILY 12	FRT DAILY 14	FRT DAILY 16	FRT DAILY 18

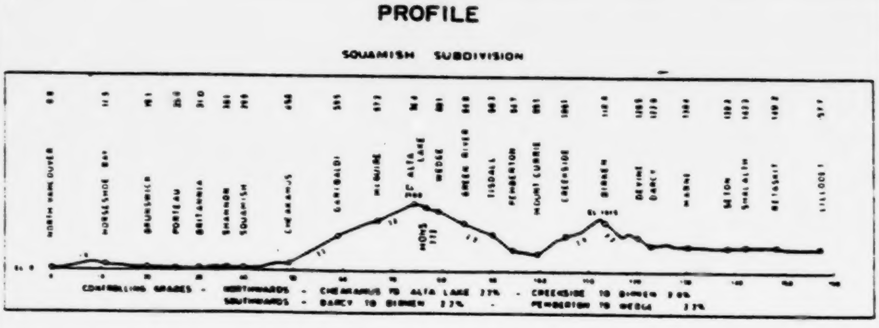


FIGURE 1-2

3. Preparation of 35 engines for LIC operation and installation of three pre-production Engine Logic Units (ELU's).

4. Similar preparation of 30 cabooses and installation of three sets of caboose electronic equipment.

5. Manufacture and installation of control point signs.

Glenayre Electronics was responsible for development of the specialized electronic equipment. In light of the results of the earlier prototype tests, Glenayre reviewed and updated the design of the on-train hardware. The Engine Logic Unit microprocessor was changed to a more powerful device, and the existing cab display was replaced by a Burroughs 6 line x 40 character plasma display driven by its own dedicated processor. The design, construction, and testing of the on-train equipment are described in (2).

TASK 3 in the development of an operational LIC System called for the design and construction of a front-end Data Collection Processor (DCP) to reduce the processing load on the central computer. Also included in TASK 3 were renovations to the central dispatch office, purchase and installation of the central office computing equipment and peripherals, and development of the software necessary for automatic tracking of LIC-equipped trains throughout the Squamish Subdivision.

TASK 3 culminated in a limited operational demonstration of the LIC System Basic Tracking functions. The demonstration involved three LIC-equipped engines and three equipped cabooses which were to be monitored over a trial period of at least seven days. The results of the Basic Tracking tests are reported in Section 3.3 of this document.

The following conclusions were reached upon completion of the Basic Tracking tests:

1. Analysis of the prototype DCP design revealed severe problems which would arise if an attempt were made to increase its functional capabilities. For this reason it was decided to redesign the DCP around the Intel Multibus architecture with a chassis and off-the-shelf printed circuit cards.

2. Difficulties with transponder detection and reporting arose in two areas: the transponders themselves and the locomotive and caboose electronics. The former problems were solved by redesign of the transponder package to effect a tighter seal against moisture. The latter required modifications to both the ELU DIGITRAC board and its associated software.

3. The locomotive odometer allows the measurement of a wheel-wear factor specific to each individual unit. This correction factor can be applied by the ELU to increase the accuracy of reported odometer readings.

4. The original chaining of the subdivision was inaccurate, which necessitated either a resurvey of the right-of-way or changes to the DCP track model.

5. The odometer should be able to recalibrate at any transponder to avoid propagation of momentary irregularities introduced as a result of wheelslip or other factors.

6. Four areas of poor communications coverage were defined: MP 11-20 (Horseshoe Bay), 44-61 (Cheakamus Canyon), 86-94 (Pemberton), and 112-125 (Darcy).

7. The time-distance train graph produced on the DCP printer gives a useful and accurate representation of both current and projected train location.

B.C. Railway and Glenayre Electronics carried out the work necessary to implement the above changes over the summer of 1981.

TASK 4 of the LIC development contract required the installation of ELU's on ten additional locomotives and ten cabooses. At the same time, Glenayre and Datap Systems were preparing the computer software necessary to implement all train tracking functions and dispatcher assist features planned for the system. Of particular interest was the development of the colour graphics train location display.

The test phase of TASK 4 involved a full operational demonstration of the LIC train tracking and dispatcher assist functions with 13 LIC-equipped trains. The evaluation period was to extend over at least one month. The Full Tracking and Dispatcher Assist function tests commenced in mid-August 1982, and concluded in January 1983.

1.2 Objectives and Scope

The purpose of this document is to summarize the work done to implement and evaluate the Train Tracking and Dispatcher Assist functions of the LIC System. The work was performed by B.C. Railway in conjunction with Glenayre Electronics Ltd. and Datap Systems.

The first four major tasks of the contract work statement have been completed as follows:

TASK 1: Preparation of the project plan and development of the system design.

TASK 2: Preparation of engines and cabooses for LIC operation and installation of the necessary communications system, including transponders to cover the whole of the Railway's Squamish Subdivision.

TASK 3: Installation of six pre-production Engine Logic Units and a central Data Collection Processor (DCP), followed by evaluation of the System's Basic Tracking functions.

TASK 4: Evaluation of the production Engine Logic Units and a single HOST/DCP central computer configuration in a Full Tracking demonstration involving up to 13 trains.

This report represents the final step in completion of TASK 4.

1.3 Outline of Report

Part 2 gives an outline of the complete LIC System and its major components and describes in detail the subset of the System used to perform the Train Tracking and Dispatcher Interface tests.

Part 3 describes the procedures used to evaluate the LIC Train Tracking functions and presents the results of both the Basic and Full Tracking tests.

Part 4 describes and evaluates the LIC Dispatcher Assist features as implemented at the time of the Full Tracking tests.

Part 5 discusses the overall reliability and availability of the LIC System.

Part 6 presents conclusions drawn from the tests described and recommendations for further work.

2.0 SYSTEM DESCRIPTION

The purpose of this part is to describe the Train Location, Identification, and Control (LIC) System. Section 2.1 is a functional overview of the complete system including Train Control. The remainder of the section deals with the LIC functions which are presently implemented and which have been satisfactorily field tested. Section 2.2 discusses system operation as it relates to the Train Tracking functions. Subsection 2.3 describes the Dispatcher Assist functions.

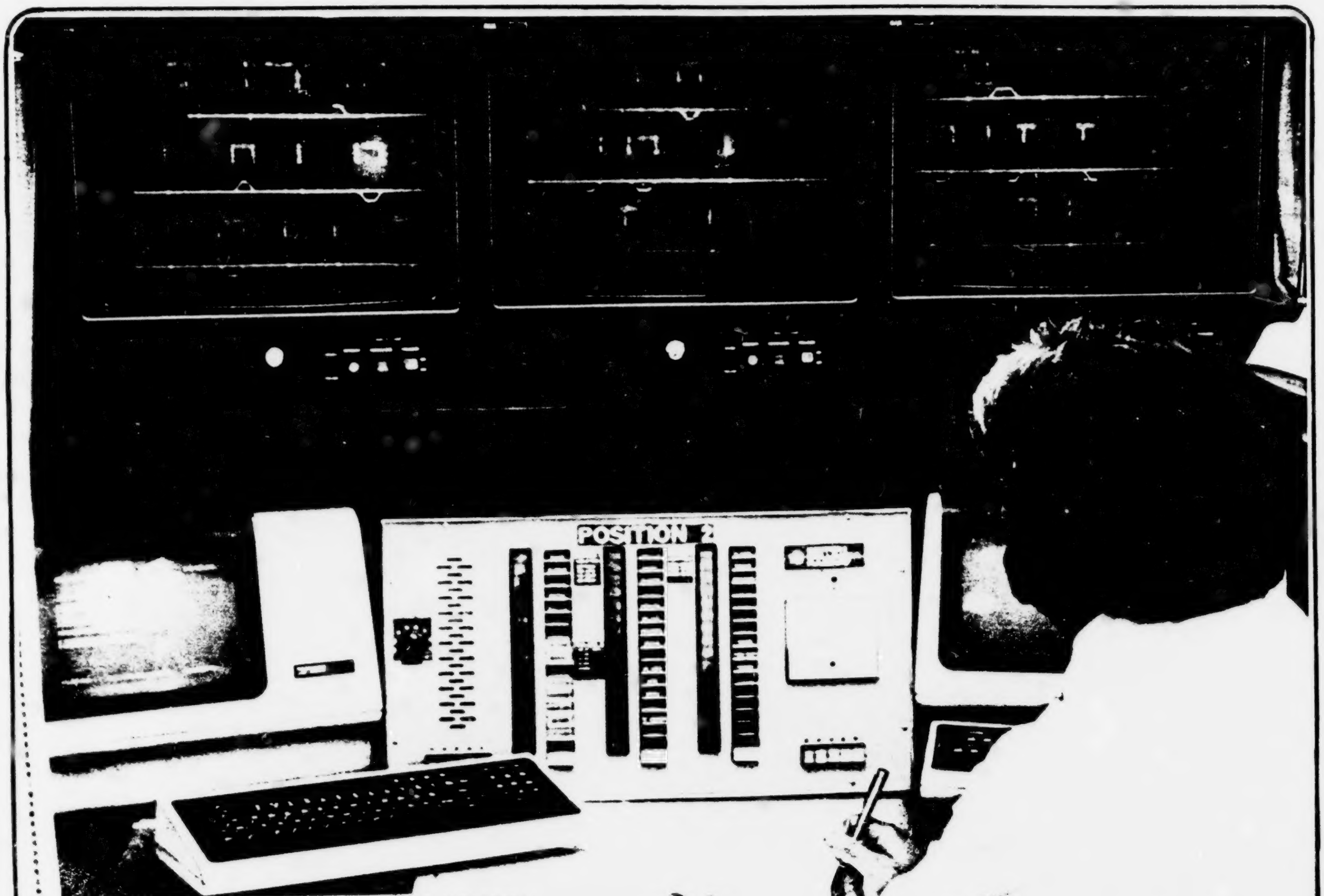
2.1 Functional Overview

The LIC System is a method of railway traffic management suitable for use on both signalized and unsignalized territory. The system is an alternative to train order or manual block control which gives increased safety at a low cost. LIC may be used to enhance Centralized Traffic Control by giving the dispatcher a more accurate picture of the location of each train within a block. In addition, the system provides an audible and visible warning to any engineman who passes a signal or block boundary without authority.

LIC is based on the concepts of instantaneous reporting of train speed, location, and direction of travel; direct dispatching; and in-cab signalling. Inherent in the system are such safety features as automatic detection of unauthorized movements. The installation and maintenance costs of LIC will be substantially less than those of a conventional track-circuit signal system.

Train dispatchers and enginemen benefit most directly from the LIC System. LIC offers the dispatcher a continuously updated graphic display showing the identity, location, and direction of every equipped train in LIC territory. The display is augmented by a permanent printed record. The dispatcher can transmit train operating instructions and other information directly and securely to the appropriate locomotive cabs. The system automatically checks both train movements and instructions and alerts the dispatcher to unsafe conditions.

LIC also simplifies the dispatcher's clerical tasks in preparing train sheets, logs, and various reports. This capability extends to the production of performance statistics and other data for management use. In short, LIC offers the train dispatcher more information and more time to use that information to plan efficiently and to deal with unexpected situations.



B.C. RAILWAY LIC DISPATCHER WORK STATION

FIGURE 2-1

LIC provides the engineman with several services which help him to concentrate on the safe and efficient operation of his train. The full LIC System includes a plain-language locomotive Cab Display Unit (CDU) which shows current speed and mileage, both to the nearest tenth, together with the next point at which movement may be restricted. With the future implementation of LIC Train Control, the dispatcher will be able to transmit orders directly to the trains affected where they will be displayed in succession on the CDU. This facility will relieve the engineman of the need to copy and repeat train orders or block clearances by radio.

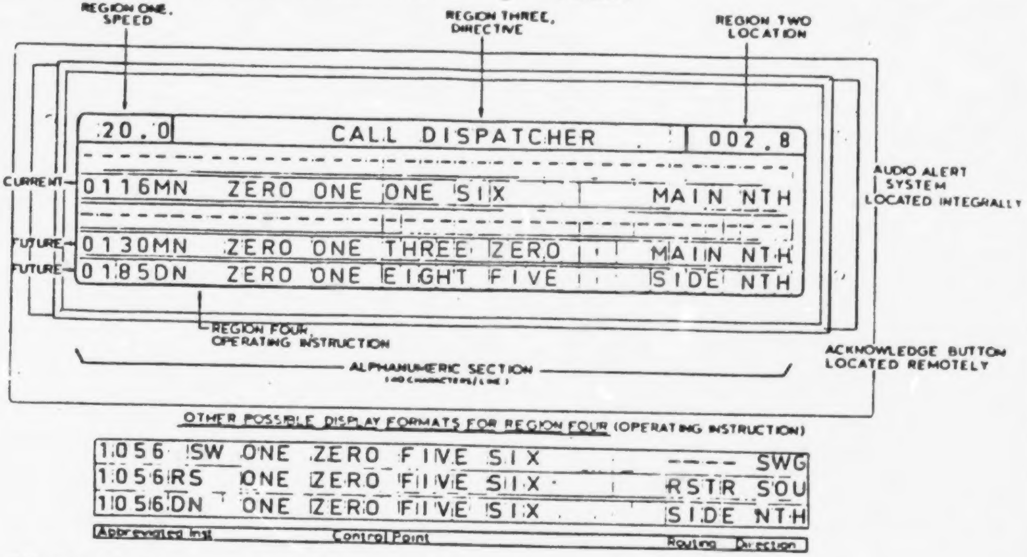

REGION ONE, SPEED
REGION THREE, DIRECTIVE
REGION TWO LOCATION
20.0
CALL DISPATCHER
002.8
CURRENT
0116MN ZERO ONE ONE SIX MAIN NTH
FUTURE
0130MN ZERO ONE THREE ZERO MAIN NTH
FUTURE
0185DN ZERO ONE EIGHT FIVE SIDE NTH
AUDIO ALERT SYSTEM LOCATED INTEGRALLY
REGION FOUR, OPERATING INSTRUCTION
ALPHANUMERIC SECTION
(40 CHARACTERS/LINE)
ACKNOWLEDGE BUTTON LOCATED REMOTELY
OTHER POSSIBLE DISPLAY FORMATS FOR REGION FOUR (OPERATING INSTRUCTION)
1056 SW ONE ZERO FIVE SIX ---- SWG
1056RS ONE ZERO FIVE SIX RSTR SOU
1056DN ONE ZERO FIVE SIX SIDE NTH
Abbreviated Inst
Control Point
Routing
Direction

FIGURE 2-2 LIC CAB DISPLAY LAYOUT

LIC offers track and time protection for Maintenance of Way personnel and work trains under written work authority. The system recognizes four distinct types of such protection:

1. EXCLUSIVE: the work limits provide protection for one train.
2. DUAL: the limits provide protection for two trains to work within the same limits protecting against each other.
3. JOINT: work limits provide protection for a train and maintenance foreman within the same limits.
4. EXCLUSIVE MAINTENANCE: work limits provide protection for maintenance foreman only.

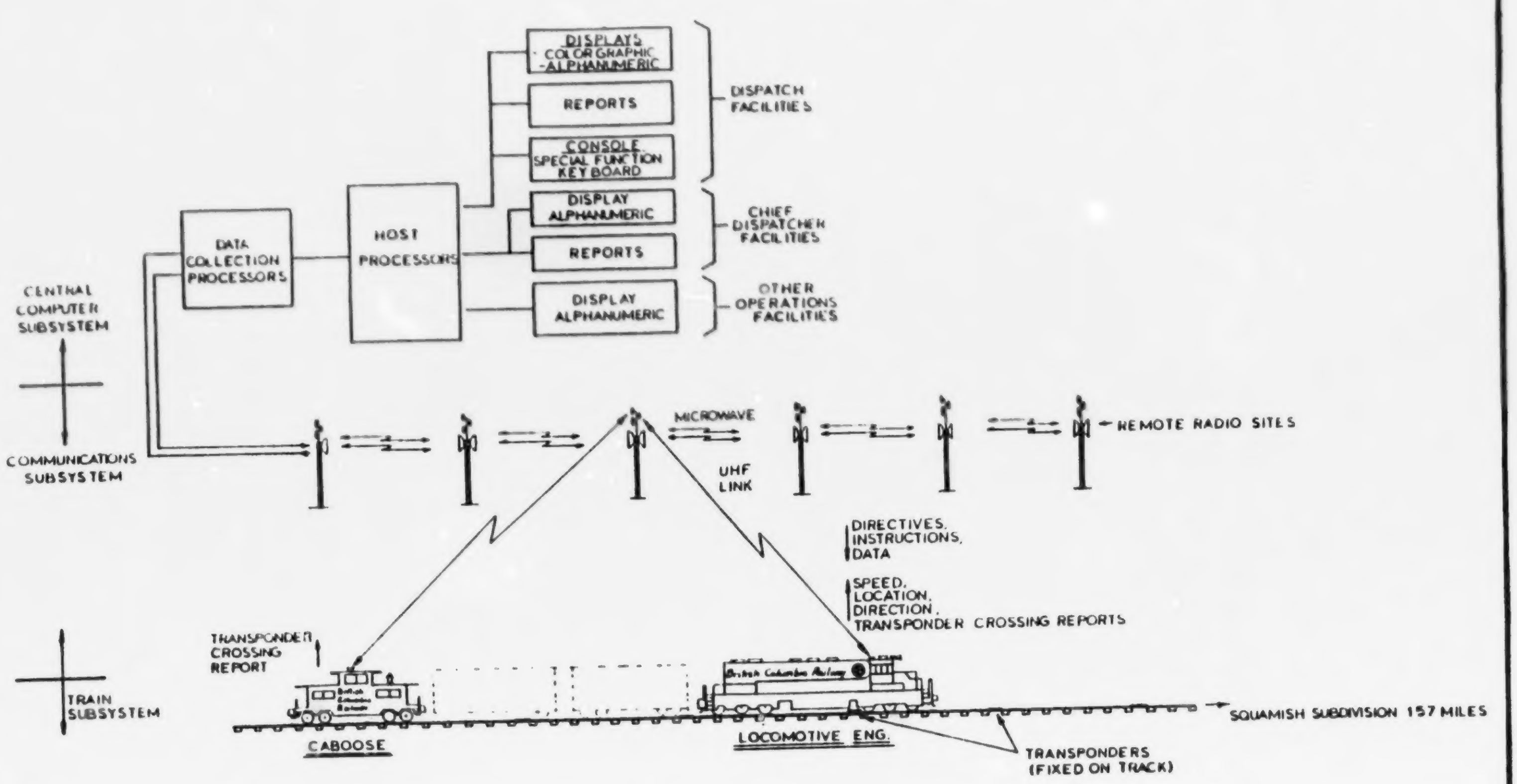
To create a written work authority, the train dispatcher must key in the track limits, time, and type of protection required on the console. After determining that no conflicts exist, LIC issues a unique authority number. The dispatcher enters this number on the written work authority form along with the appropriate track, time, and other information. The dispatcher can then transmit the authority to the conductors, enginemen, and maintenance foremen concerned by voice radio. Cancellation of the authority must be acknowledged by all parties involved before the dispatcher enters it at the keyboard. Until that time, LIC will not permit any movement into the work limits.

Under LIC operation, a central computer in the dispatching office polls each train in turn by digital radio in order to obtain complete operating data. This information is used to generate a continuous record of all train locations. The dispatcher can enter train movement instructions which are automatically validated, transmitted to the train, and presented to the engineman on the locomotive cab display. LIC uses redundant hardware wherever possible, together with a highly secure communications protocol, to ensure the greatest degree of safety and reliability.

LIC comprises three major subsystems: the Central Computer Subsystem (CCS), the Train Subsystem (TSS), and the Communications Subsystem (CMS). The overall system configuration is illustrated in Figure 2-3. The remainder of this section describes the components of each subsystem.

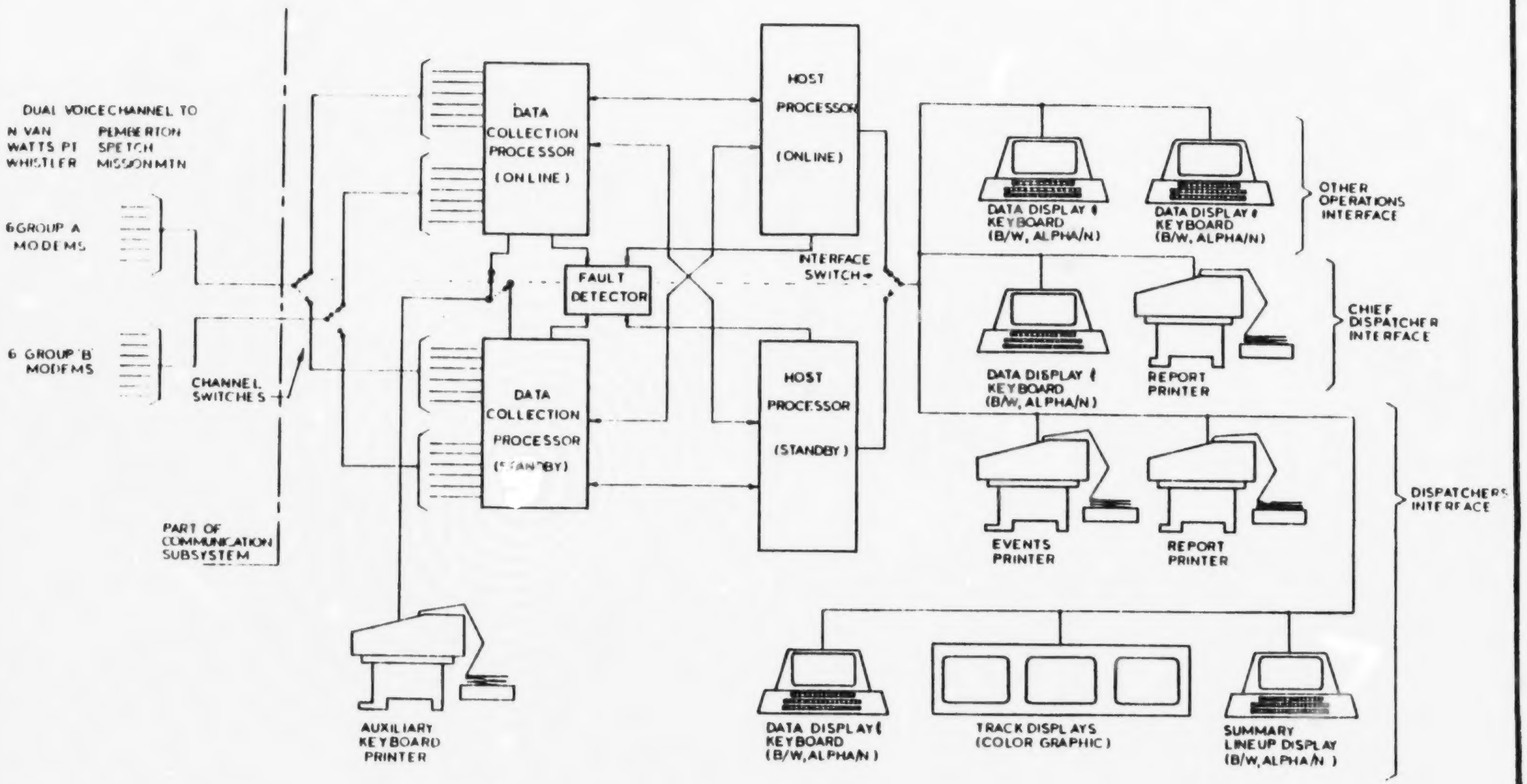
2.1.1 Central Computer Subsystem (CCS)

The Central Computer Subsystem is located at the dispatching office. Figure 2-4 is a block diagram of the subsystem, and Appendix "A" contains a detailed description of its hardware components. Processing in the CCS is divided between the main computer or HOST and a front-end Data Collection Processor (DCP). The two processors communicate continuously via a 9600-baud asynchronous serial data link.


DISPLAYS
COLOR GRAPHIC
-ALPHANUMERIC
REPORTS
CONSOLE
SPECIAL FUNCTION
KEY BOARD
DISPATCH FACILITIES
DISPLAY
ALPHANUMERIC
REPORTS
CHIEF DISPATCHER FACILITIES
DISPLAY
ALPHANUMERIC
OTHER OPERATIONS FACILITIES
DATA COLLECTION PROCESSORS
HOST PROCESSORS
CENTRAL COMPUTER SUBSYSTEM
COMMUNICATIONS SUBSYSTEM
MICROWAVE
UHF LINK
REMOTE RADIO SITES
DIRECTIVES, INSTRUCTIONS, DATA
SPEED, LOCATION, DIRECTION, TRANSPONDER CROSSING REPORTS
TRANSPONDER CROSSING REPORT
TRAIN SUBSYSTEM
CABOOSE
LOCOMOTIVE ENG.
British Columbia Railway
SQUAMISH SUBDIVISION 157 MILES
TRANSPONDERS (FIXED ON TRACK)

BLOCK DIAGRAM OF LIC SYSTEM

FIGURE 2-3


DUAL VOICECHANNEL TO
N VAN
WATTS PT
WHISTLER
PEMBERTON
SPETCH
MISSIONMTN
6GROUP A MODEMS
6 GROUP 'B' MODEMS
CHANNEL SWITCHES
PART OF COMMUNICATION SUBSYSTEM
DATA COLLECTION PROCESSOR (ONLINE)
DATA COLLECTION PROCESSOR (STANDBY)
FAULT DETECTOR
HOST PROCESSOR (ONLINE)
HOST PROCESSOR (STANDBY)
INTERFACE SWITCH
AUXILIARY KEYBOARD PRINTER
DATA DISPLAY & KEYBOARD (B/W, ALPHA/N)
DATA DISPLAY & KEYBOARD (B/W, ALPHA/N)
OTHER OPERATIONS INTERFACE
DATA DISPLAY & KEYBOARD (B/W, ALPHA/N)
REPORT PRINTER
CHIEF DISPATCHER INTERFACE
EVENTS PRINTER
REPORT PRINTER
DATA DISPLAY & KEYBOARD (B/W, ALPHA/N)
TRACK DISPLAYS (COLOR GRAPHIC)
SUMMARY LINEUP DISPLAY (B/W, ALPHA/N)
DISPATCHERS INTERFACE

CENTRAL COMPUTER SUBSYSTEM

FIGURE 2-4

The microprocessor-based DCP is responsible for control of the communications channel; collection of data from each train under LIC control; and validation of messages to and from the HOST. For example, when the DCP receives a control point instruction from the HOST, it must check its own records for potential conflicts before it will acknowledge the message and transmit it to the appropriate ELU.

The DCP maintains four important data structures:

1. A track model listing the serial number and mileage of every active transponder - essentially a subset of the HOST computer track model (see Appendix "B").
2. A communications model giving the radio coverage of each remote communications site (see 2.1.3 below).
3. A train data base which records for each train known to the system the identifier and most recent status information for each ELU in the train; the latest speed and direction from the lead unit ELU; and up to twelve most recent transponder crossings for the lead and end-of-train ELU's.
4. An occupancy/authority data base which records for each block in the territory the identifier of any train wholly or partially occupying the block as well as the identifier of any train holding authority to enter that block.

One or more printers are connected to the DCP for the production of train graphs (Section 2.2.4), a significant events log, and other operating reports.

The HOST processor, a Digital PDP-11/44 minicomputer, is responsible for the train dispatcher's interface to the LIC System. The dispatcher interacts with LIC via colour graphics displays and one or more alphanumeric keyboard displays. All of these devices are maintained by the HOST processor which also provides the following dispatcher assist functions:

1. Automatic train sheet manipulation.
2. Colour graphics train location display.
3. Dispatcher displays and reports.
4. Dispatcher shift change procedure.

In addition, the HOST system maintains its own significant events log and printer. The system specification defines a significant event as any occurrence which changes the state of the system. Such events may be generated by trains operating in LIC territory, by system users such as the dispatcher, and by the computers themselves. Six categories of event may be logged, ranging from System Alarms (e.g., Online HOST or DCP system failure) to System Events (e.g., transponder crossing report) and User Activities (e.g., train sheet data entry or display). All events are to be logged by the system within 3 seconds of their detection by the HOST and within 1 1/2 minutes of their actual occurrence.

When the train control aspect of LIC is implemented, the HOST processor will interpret the dispatcher's instructions and perform rigorous tests for their validity before generating the necessary control point messages and passing them to the DCP for transmission. The DCP in turn will search its occupancy/authority data base for conflicts in order to validate any such message before initiation of a control point transaction with the ELU.

In a fully-configured LIC System, both HOST and DCP are backed up by duplicate processors. A combination of automatic and manual switching permits any HOST-DCP pair to be interconnected, thereby ensuring maximum system availability in the event of hardware failure. Should the HOST fail and no backup be available, the dispatcher's console can be connected directly to the DCP to perform the basic train tracking functions.

The Central Computer Subsystem as implemented for the Full Tracking tests described herein consisted of a single HOST and single DCP.

2.1.2 Train Subsystem (TSS)

The TSS includes both trackside and train-mounted equipment, as indicated in the block diagram (Figure 2-5). The trackside equipment consists of passive transponders mounted on the roadbed at each point at which positive train identification is required. Train-mounted LIC equipment comprises processing and communications hardware and is found on both engines and cabooses. The transponders themselves and that part of the locomotive equipment required for their detection comprise Glenayre's DIGITRAC system.

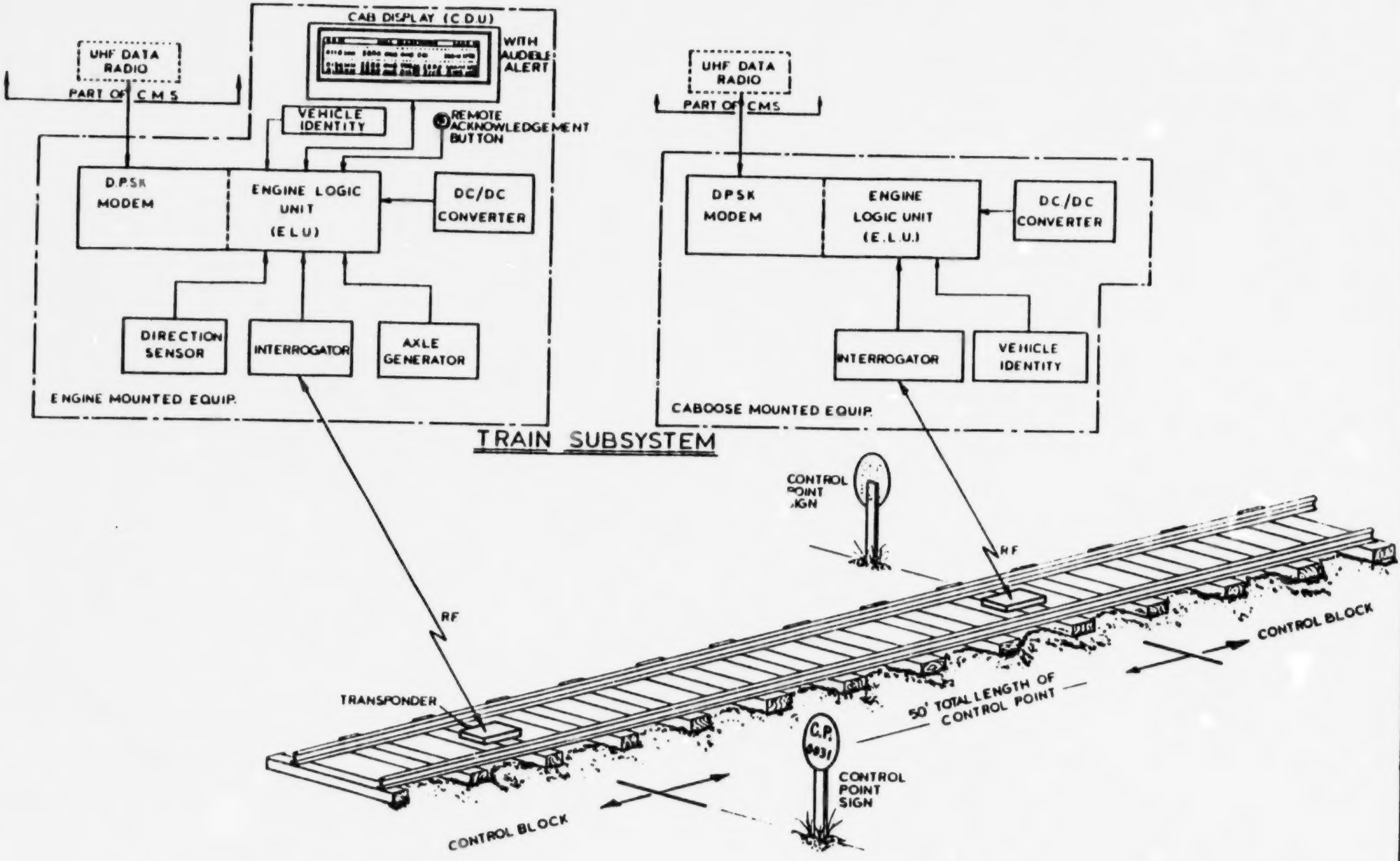

UHF DATA RADIO
PART OF CMS
CAB DISPLAY (C.D.U)
WITH AUDIBLE ALERT
VEHICLE IDENTITY
REMOTE ACKNOWLEDGEMENT BUTTON
D.P.S.K MODEM
ENGINE LOGIC UNIT (E.L.U)
DC/DC CONVERTER
DIRECTION SENSOR
INTERROGATOR
AXLE GENERATOR
ENGINE MOUNTED EQUIP.
UHF DATA RADIO
PART OF CMS
DPSK MODEM
ENGINE LOGIC UNIT (E.L.U.)
DC/DC CONVERTER
INTERROGATOR
VEHICLE IDENTITY
CABOOSE MOUNTED EQUIP.
TRAIN SUBSYSTEM
CONTROL POINT SIGN
RF
RF
TRANSPONDER
CONTROL BLOCK
50' TOTAL LENGTH OF CONTROL POINT
C.P. 0031
CONTROL POINT SIGN
CONTROL BLOCK

FIGURE 2-5 TRAIN SUBSYSTEM

LIC locomotive and caboose equipment (Figures 2-6 & 2-7) includes several major components. The heart of the locomotive equipment is the microprocessor-based Engine Logic Unit (ELU) which interfaces to all of the other components and transfers data between the train and the central computer. On the underside of the engine is a DIGITRAC Interrogator Coil Unit (ICU) which activates transponders and receives their transmitted identity numbers. An axle-mounted pulse generator allows measurement of the rate and distance of train travel. An indication of the direction of travel (Forward/Reverse/Stopped) is derived from the position of the engineman's forward/reverse lever.

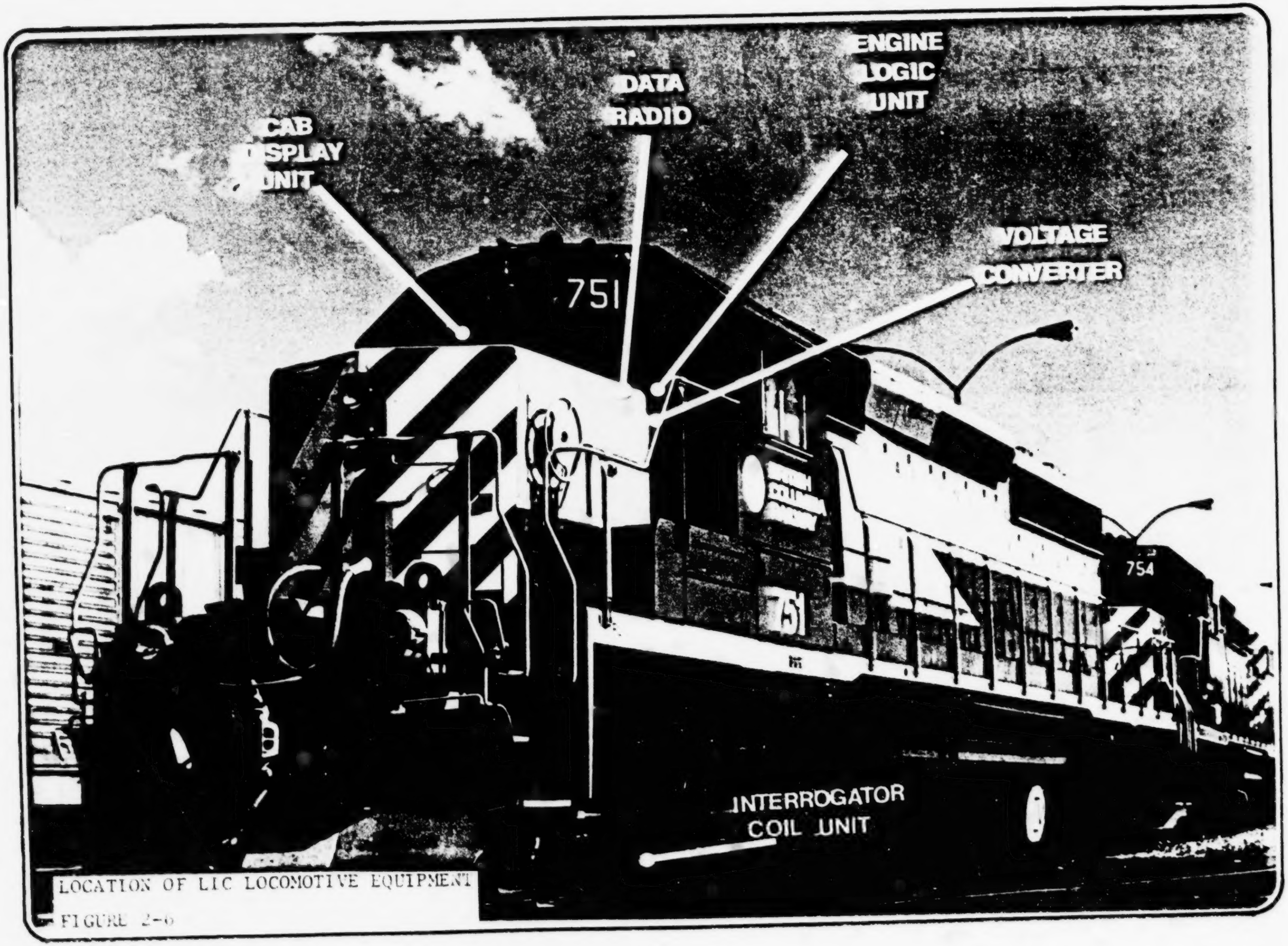
The locomotive Cab Display Unit (CDU) provides the engineman with a digital odometer and speedometer, together with a plain-language display of operating instructions and other information. The ELU communicates with fixed stations by means of a DPSK modem and UHF (450 MHz) radio transceiver mounted on the locomotive (see Section 2.1.3).

Caboose-mounted LIC equipment is a subset of the locomotive equipment consisting of: an Engine Logic Unit; an Interrogator Coil Unit; and a UHF radio and modem, together with the necessary voltage converters and power supplies. The axle generator, direction sensor, Cab Display Unit, and their ELU interfaces are omitted. Caboose equipment is only capable of reporting transponder crossings.

For the purposes of the full tracking tests, train equipment was mounted on 13 freight engines and 13 cabooses. A total of 148 transponders were placed in locations which covered the entire Squamish Subdivision from North Vancouver to Lillooet.

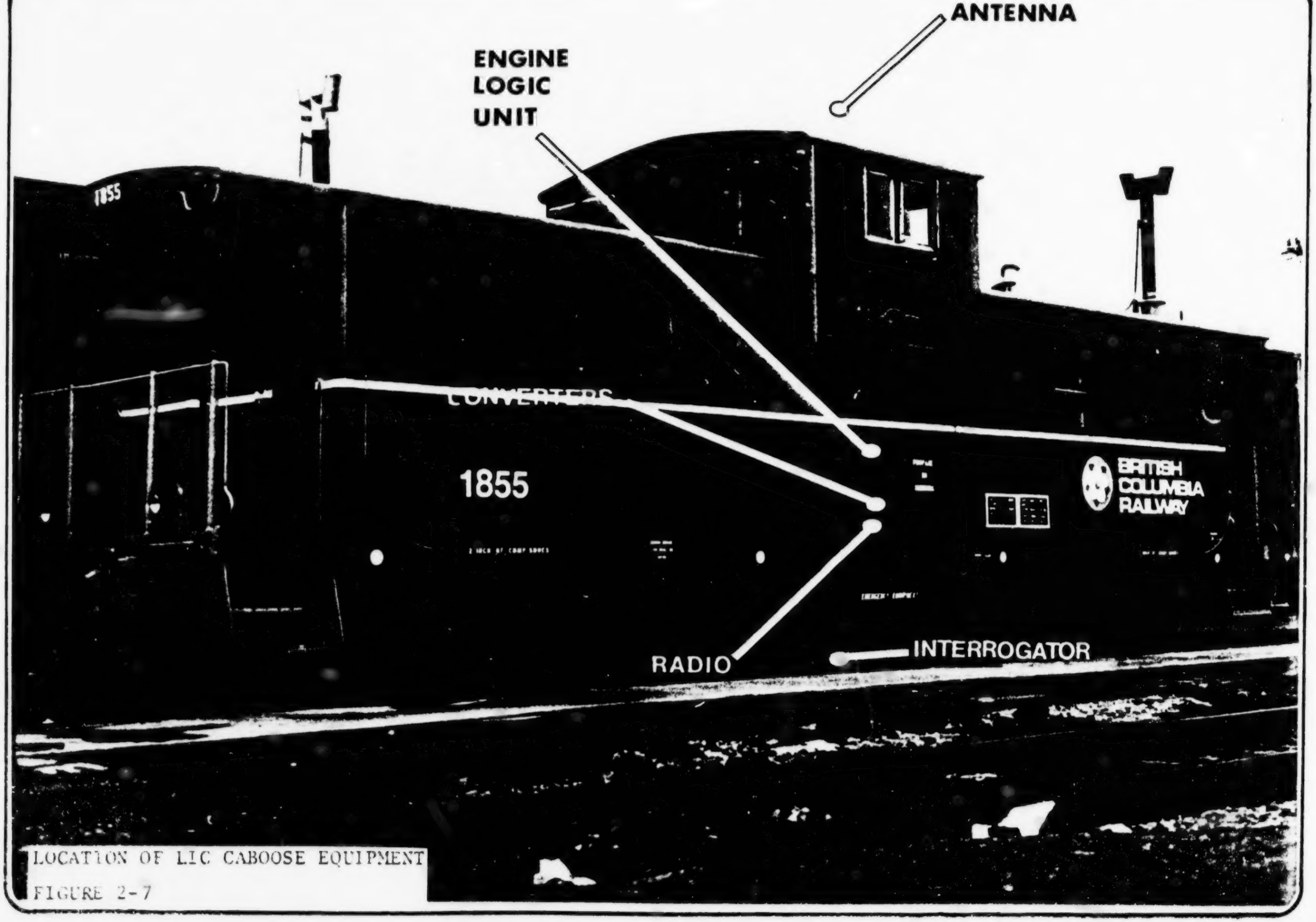
2.1.3 Communications Subsystem (CMS)

CMS provides the essential link between the Central Computer and Train Subsystems. As the Subsystem block diagram (Figure 2-8) shows, CMS has two major components: a mobile digital radio network linking LIC-equipped trains and remote communications sites; and a communications trunk consisting of microwave and landline links between the remote sites and the central office.


CAB
DISPLAY
UNIT
DATA
RADIO
ENGINE
LOGIC
UNIT
VOLTAGE
CONVERTER
751
754
751
INTERROGATOR
COIL UNIT

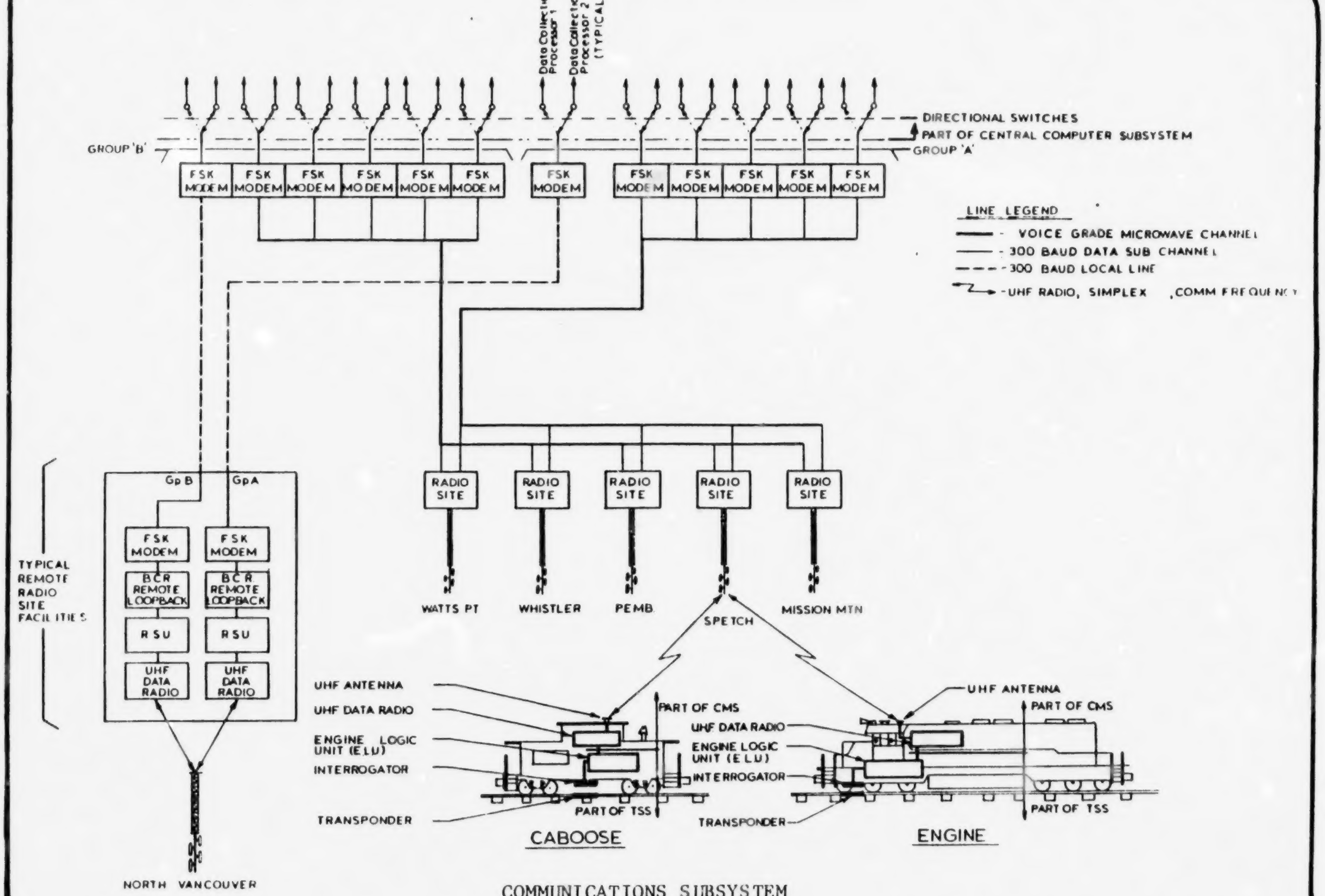
LOCATION OF LIC LOCOMOTIVE EQUIPMENT

FIGURE 2-6


ANTENNA
ENGINE
LOGIC
UNIT
CONVERTERS
1855
1855
BRITISH
COLUMBIA
RAILWAY
RADIO
INTERROGATOR

LOCATION OF LIC CABOOSE EQUIPMENT

FIGURE 2-7


Data Collection Processor 1
Data Collection Processor 2 (TYPICAL)
DIRECTIONAL SWITCHES
PART OF CENTRAL COMPUTER SUBSYSTEM
GROUP 'B'
GROUP 'A'
FSK MODEM
LINE LEGEND
- VOICE GRADE MICROWAVE CHANNEL
- 300 BAUD DATA SUB CHANNEL
- 300 BAUD LOCAL LINE
- UHF RADIO, SIMPLEX ,COMM FREQUENCY
RADIO SITE
WATTS PT
WHISTLER
PEMB.
SPETCH
MISSION MTN
TYPICAL REMOTE RADIO SITE FACILITIES
Gp B
Gp A
BCR REMOTE LOOPBACK
RSU
UHF DATA RADIO
NORTH VANCOUVER
UHF ANTENNA
UHF DATA RADIO
ENGINE LOGIC UNIT (ELU)
INTERROGATOR
TRANSPONDER
PART OF CMS
PART OF TSS
CABOOSE
ENGINE

COMMUNICATIONS SUBSYSTEM

FIGURE 2-8

The mobile part of the digital radio network is provided by a DPSK modem and UHF transceiver on every LIC-equipped vehicle. The fixed end of the circuit is handled by UHF tranceivers at each of six remote communications sites covering the entire Squamish Subdivision.

The UHF radios receive and transmit DPSK encoded data between trains and wayside microwave drop repeater sites. Remote Site Units (RSU's, Figure 2-9) at each communications site accept DPSK encoded data from the radios at one interface and logic-level (RS-232-C) data from a 300-baud FSK modem at another interface.

FSK signals from five of the six RSU's are frequency-division multiplexed onto a single voice grade channel on the microwave trunk. The sixth data subchannel uses a direct landline link between the North Vancouver remote site and the central office. A second voice channel, together with dual RSU's and transceivers at each remote site, provides complete redundancy for backup. The two channels, designated A and B, are used alternately unless one has failed.

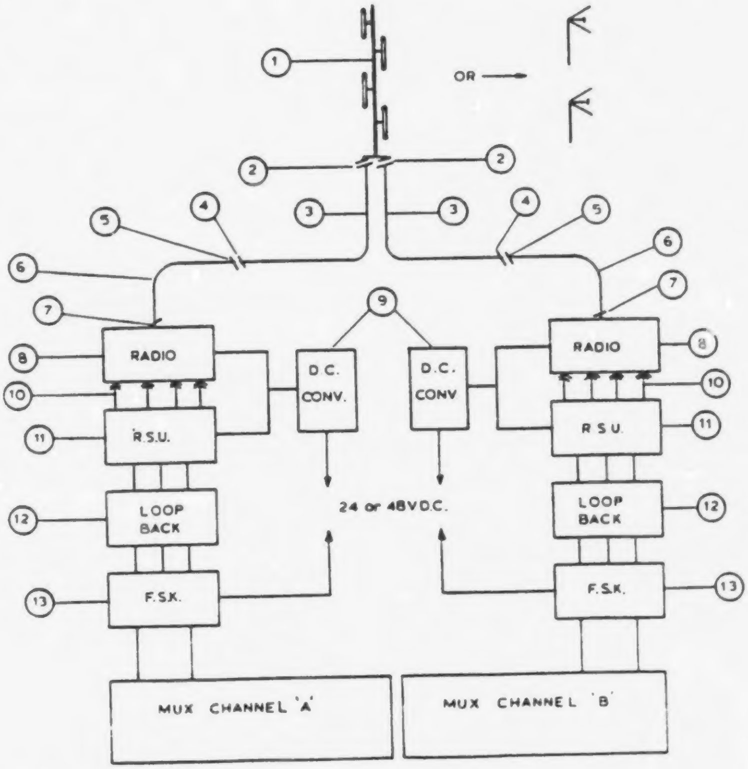
2.2 Train Tracking Functions

Tracking is the process by which the LIC central computer maintains a continuous record of the identity and location of every equipped train in its territory. Included in the tracking function is the retrieval, processing, and storage of all information related to the status of the train-mounted equipment. Tracking-only mode involves no control functions, and no dispatcher input is required other than use of the facilities provided to display or print reports.

Proper tracking depends on successful performance of four functions:

1. Transponder reporting.
2. Engine odometer calibration.
3. ELU-DCP communications.
4. Train location.

This section describes the manner in which the four tracking functions are carried out.


OR
RADIO
D.C. CONV.
D.C. CONV
R.S.U.
LOOP BACK
F.S.K.
24 or 48VDC.
MUX CHANNEL 'A'
MUX CHANNEL 'B'
1
2
3
4
5
6
7
8
9
10
11
12
13

① DUAL ARRAY UHF ANTENNA or DIREC ANTENNAS
② L44 W CONNECTOR
③ L OF 4 50 FOAM HELIAX
④ L44U CONNECTOR
⑤ 3-330830-1 CONNECTOR
⑥ 621-111 RG 8 CO AX
⑦ 3-330830-1 CONNECTOR
NOT SHOWN: RADIO MTG. TRAY

⑧ UHF DATA RADIO
⑨ 24/48 to 12VDC CONVERTERS
⑩ RADIO CABLE HARNESS
⑪ R S.U.
⑫ LOOP BACK PANEL
⑬ F S K MODEMS
NOTE: REFER TO C-5210 FOR C S S REQUIRMENT AT CENTRAL.

LIC EQUIPMENT AT MICROWAVE SITE

FIGURE 2-9

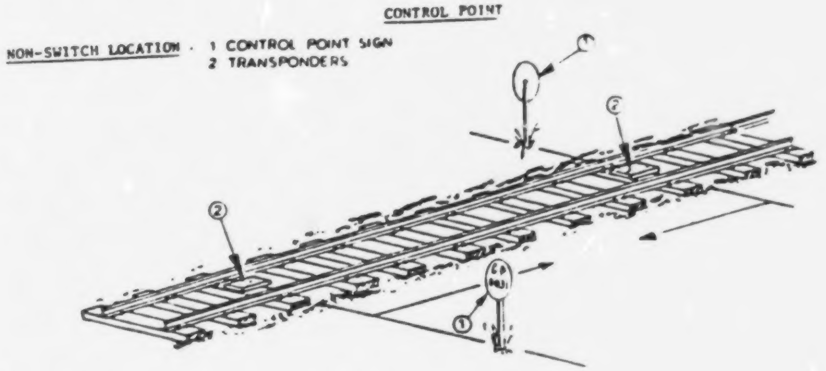

CONTROL POINT
NON-SWITCH LOCATION - 1 CONTROL POINT SIGN
2 TRANSPONDERS
①
②
②
CP
①

FIGURE 2-10

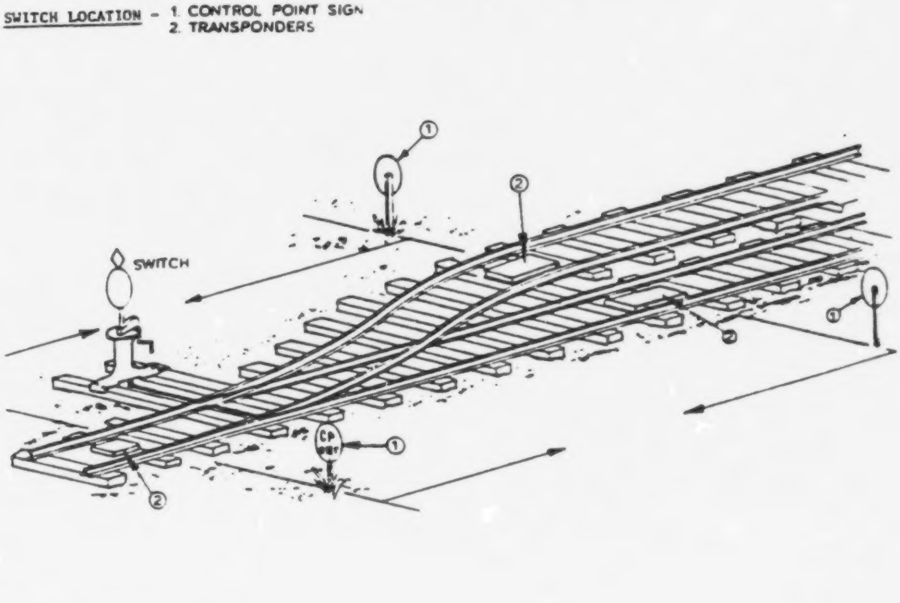

SWITCH LOCATION - 1. CONTROL POINT SIGN
2. TRANSPONDERS
①
②
SWITCH
②
①
CP
①
②

FIGURE 2-11

2.2.1 Transponder Reporting

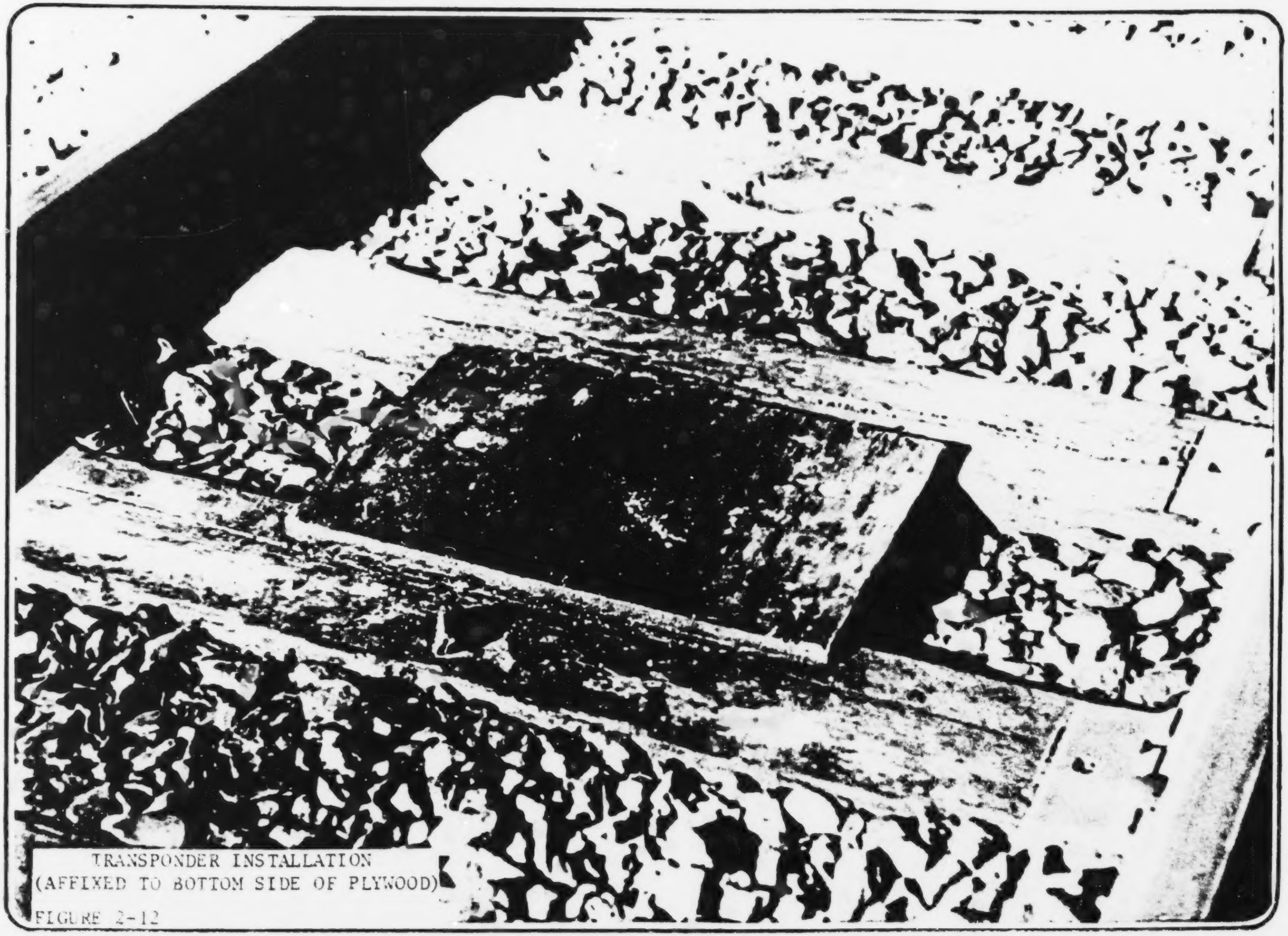
LIC operation requires that an equipped vehicle have the means to detect, correctly identify, and report every transponder crossed. Transponder crossing data are used to indicate specific track occupancy, to infer direction of movement, and to calibrate the engine odometer (Subsection 2.2.2 below). Transponders are placed at the boundaries of LIC territory, at specific main track switches, and at other locations within the territory as required.

Control points are designated locations used as block limits in the LIC System. Every control point is marked by at least two transponders and accompanying wayside signs (Figure 2-10). The order in which a train crosses the two transponders shows its absolute direction at the time (e.g., northward or southward).

A control point at a switch requires three transponders which are designated A (Approach), M (Main), and D (Diverging) and are placed at the fouling points of the switch (Figure 2-11). The transponder pair activated by a movement over a switch indicates whether the main or diverging route has been taken. In future development of LIC train control, the system will use this information to infer the position of each switch. When a switch is found to have been lined for a route other than the main track, it will be flagged by the computer until the dispatcher has received and entered a switch OS. The purpose of the flag is to protect against authorization of main track movements over an incorrectly lined switch.

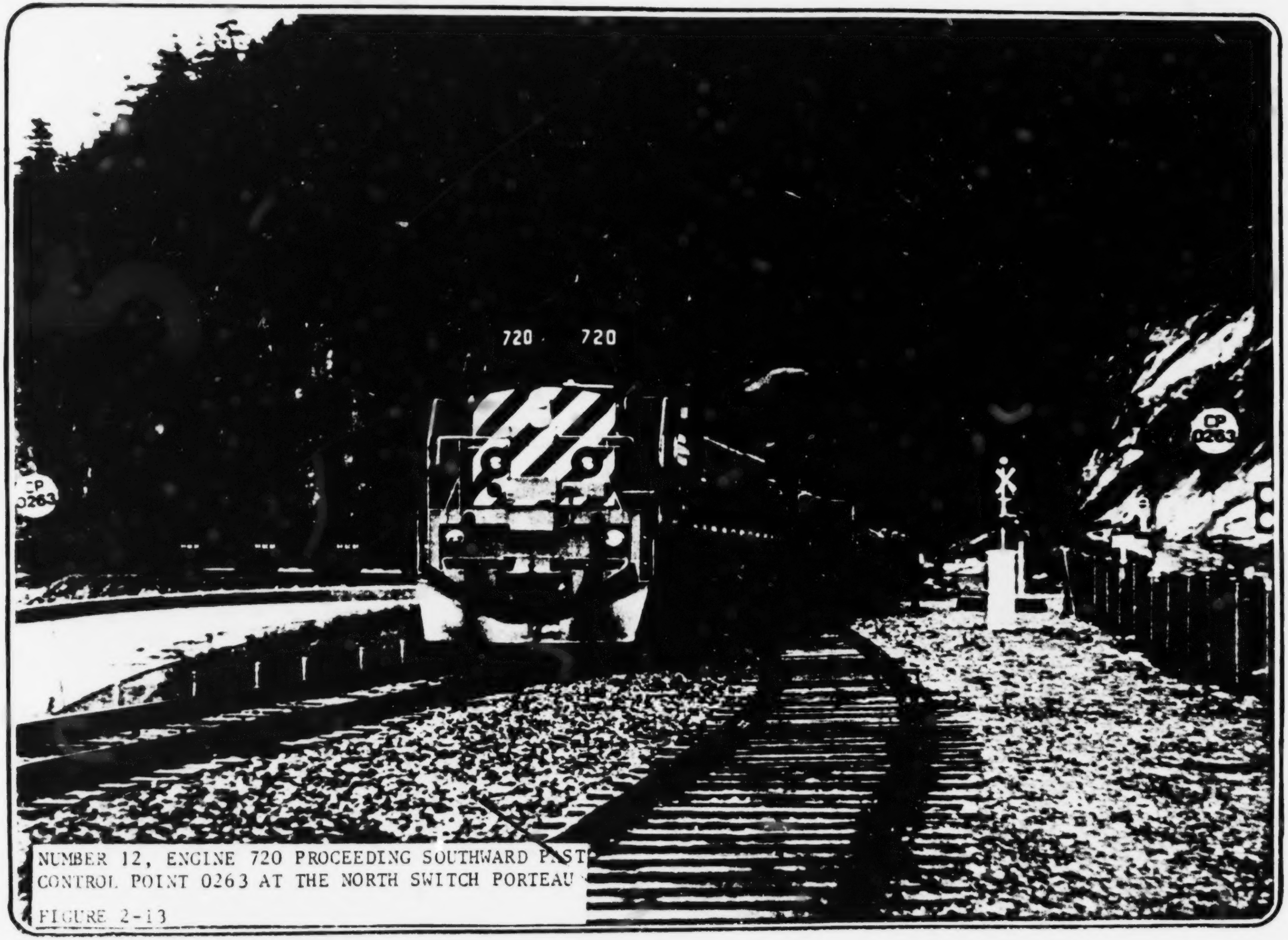
The transponder itself is a passive device which is energized by radio-frequency energy emitted by the Interrogator Coil Unit on an engine passing overhead. Upon activation, the transponder continuously broadcasts its unique coded identifier. Appendix "C" is an extract from the Glenayre DIGITRAC System Technical Manual which lists the specifications of the transponders, interrogator, and ICU controller.

The ICU controller decodes the transponder serial number by averaging seven received data frames. If two consecutive bad frames are received, the averaging process must be restarted.



TRANSPONDER INSTALLATION
(AFFIXED TO BOTTOM SIDE OF PLYWOOD)

FIGURE 2-12


720 720
CP 0263
CP 0263

NUMBER 12, ENGINE 720 PROCEEDING SOUTHWARD PAST CONTROL POINT 0263 AT THE NORTH SWITCH PORTEAU

FIGURE 2-13

When the ELU receives a transponder number it creates a record containing the following data:

1. Transponder number.
2. Transponder location as estimated by the engine odometer.
3. Engine direction (forward/reverse/stopped).
4. Speed
5. Certain other system status indicators including odometer calibrate flag (2.2.2).

The transponder record is placed in a first-in, first-out buffer to await transmission to Central. In addition to the data listed above, each queued record has associated with it a count of the time elapsed since the actual transponder crossing. The time is recorded in 15-second increments, to a maximum of one hour. The transponder queue may contain up to eight such records.

Polling is the regular and periodic transmission of messages by the DCP to individual ELU's in order to solicit status and transponder crossing data. The polling interval can vary from 5 to 90 seconds depending on the number of active ELU's and the proportion of priority messages transmitted by the DCP. When the DCP polls a particular ELU, the latter reports all transponder crossings in its buffer. Records are removed from the queue successively as each is acknowledged by the DCP. When no transponder records remain to be sent, or if none existed at the time of polling, the ELU transmits a status message which indicates the buffer is empty.

A "speak-up" function permits identification of movements in LIC territory which were previously unknown to the system. This function is used when a train first enters LIC territory and also provides a means whereby a train inadvertently lost by the system, e.g., through temporary communications failure, can be relocated.

An ELU will speak-up or initiate transmission under the following conditions:

1. The ELU has declared communications failure because it has not received a polling message in the last five minutes and at least one transponder record remains in its buffer.

2. A non-communicating ELU, i.e., one which is not yet included in the polling cycle, detects a transponder.

The ELU transmits the speak-up message three times at 1/2 second intervals, repeating the procedure at random every 5 to 10 seconds until it receives an acknowledgement by a normal polling request.

2.2.2 Odometer Calibration

Every LIC-equipped engine is fitted with an axle pulse generator which produces a stream of pulses as the wheels rotate. If the distance travelled between pulses is known, then the ELU can use the pulse count as the basis of an engine odometer. The count for a given distance clearly depends on wheel circumference, and this figure will vary from one class of engine to another. For this reason, the ELU mounting base on each engine has a basic wheel factor for that engine strapped into it.

In order for the ELU to determine the engine's actual mileage, the odometer must be initialized and an absolute direction indicator set. Odometer calibration is carried out on the ELU's receipt of a "calibrate" message giving a transponder number, its acutal mileage, and an increment/decrement flag to indicate absolute direction. When the ELU detects the assigned transponder, it sets the odometer to the figure indicated. This procedure is known as simple calibration. The odometer is subsequently incremented or decremented according to the engine's direction of travel.

(The lead engine of a northward train normally would increment its odometer travelling forward and decrement it in reverse; on a southward train it would do the opposite.)

An additional calibration factor permits correction for engine wheel wear. The ELU computes the wear factor from the ratio of the odometer-derived distance between two transponders to the "true" distance. The latter is the difference between the two transponder mileages as stored in the DCP track model. This procedure, referred to as full calibration, normally takes place only at the start of a trip. It is carried out on command from CCS and must have been preceded by a simple calibration.

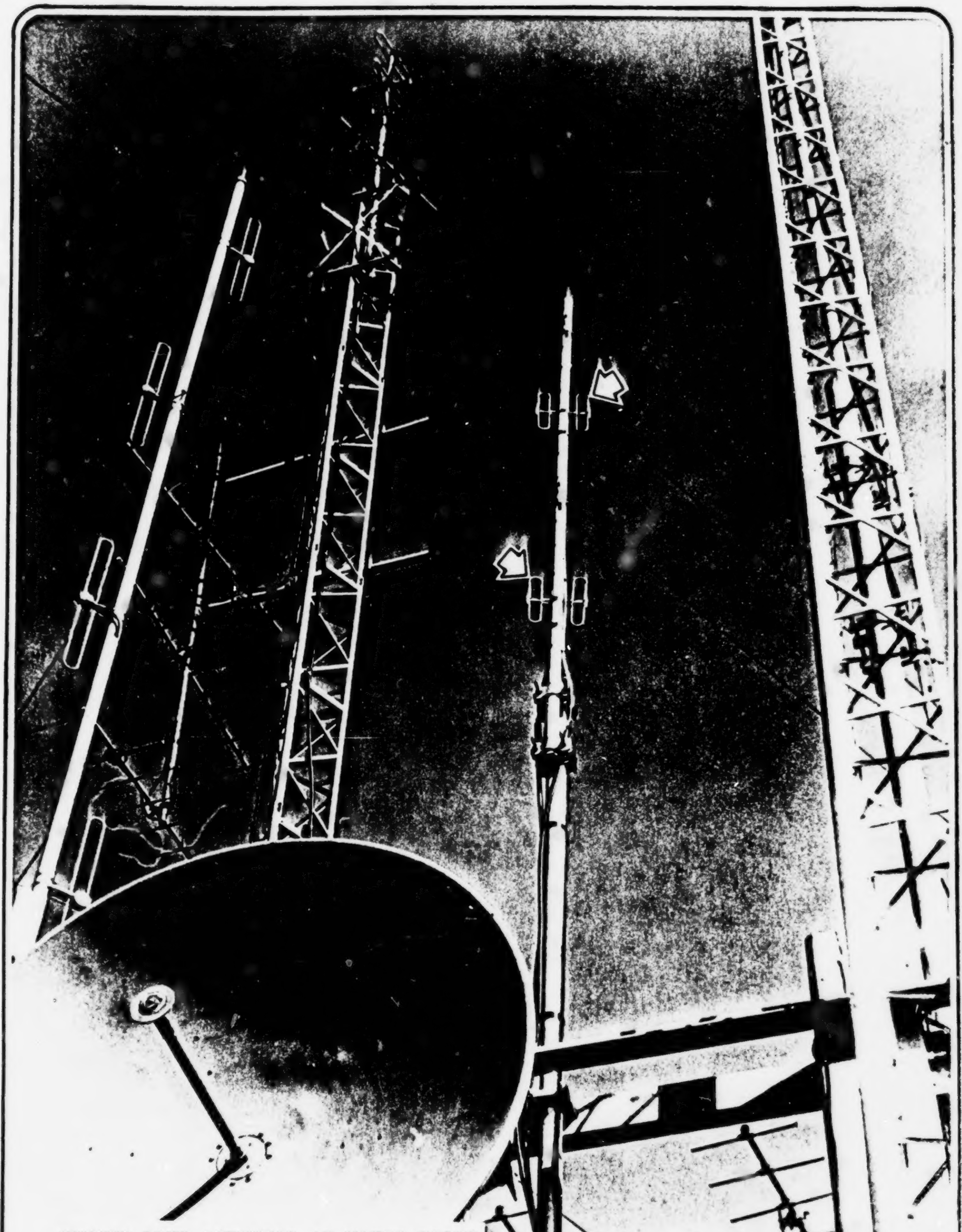
The ELU calculates odometer readings to the nearest 0.01 mile and reports them to CCS with this precision (the cab display shows only the nearest 0.1 mile). Should the mileage reported at any transponder crossing differ from the known value by more than 0.05 mile, Central initiates a simple calibration at the next transponder distance by at least one mile. The DCP's internal logic takes account of the pending recalibration and will ignore the mileage reported at any intervening transponder.

If the odometer error is greater than 0.1 mile on two successive calibration attempts, the ELU will declare odometer failure by setting an "uncalibrated" flag in its status message. The same flag is set by the ELU power-on sequence, so the odometer is uncalibrated when the engine first enters LIC territory. In addition, the ELU can declare itself uncalibrated if the mileage reported is outside the range -999 to +999 miles or if the calculated speeds exceeds 100 miles per hour.

2.2.3 ELU-DCP Communications

LIC relies heavily on data communications by radio. Subsection 2.1.3 describes the overall arrangement of the Communications Subsystem. This section discusses the two main factors which influence communications performance: radio coverage of LIC territory; and choice of communications technique such as modulation, data rate, and error recovery.

Radio propagation at UHF requires a line of sight path between transmitting and receiving antennas for best performance. This ideal will not always be attained in a network of fixed and mobile stations operating in mountainous terrain. B.C. Railway's microwave site locations between North Vancouver and Lillooet were originally chosen to optimize track coverage for VHF train radio, and the LIC remote site antennas (Figure 2-14) are placed to take advantage of this fact. Figure 2-15 illustrates the approximate geographical coverage of each site.



REMOTE SITE ANTENNAS AT WATTS POINT
(ARROW INDICATES LIC ANTENNAS)

FIGURE 2-14

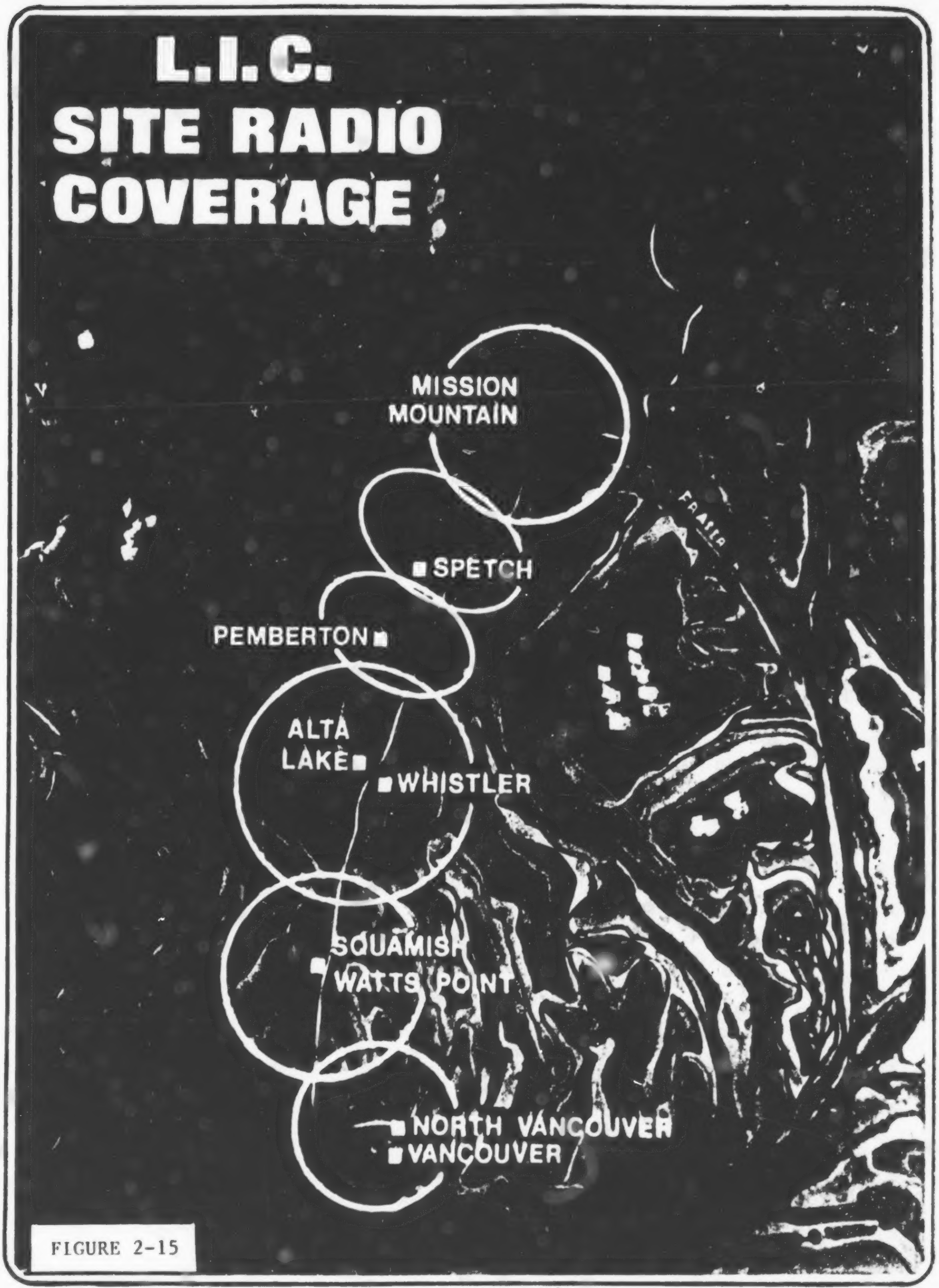

L.I.C.
SITE RADIO
COVERAGE
MISSION
MOUNTAIN
FRASER
SPETCH
PEMBERTON
ALTA
LAKE
WHISTLER
SQUAMISH
WATTS POINT
NORTH VANCOUVER
VANCOUVER

FIGURE 2-15

Radio coverage is still far from perfect. Signals from a moving train are intermittently blocked or otherwise interfered with by rock cuts, tunnels, and cliff faces. LIC communications techniques were chosen to give the maximum probability of successful data transfer under such conditions. A preliminary analysis of communications capacity (Appendix "D") based on site coverage, message lengths, average train speed, and other factors was made. The results showed that with the present communications system, 10 trains could be handled, provided that the message transaction success rate between the ELU's and central was a minimum of 75% and was uniform along the subdivision. The number of trains handled was shown to increase to about 22, if simultaneous communication with trains using multiple separate remote sites was adopted in the future. More recent studies and measurements have shown that there are additional factors, such as increased radio turn-on times and increased message lengths, which reduce performance.

Messages between DCP and ELU are divided into blocks of four 8-bit characters transmitted at 300 baud. The last 8-bit word in each block contains five bits of BCH error detection code and a parity bit. If an error in a block is detected, the received message will be ignored.

The communications protocol requires that the DCP receive an error-free reply from the ELU addressed in any given message. If no such reply is recognized within a defined wait period, then the DCP will retransmit the message according to the rules outlined in the following paragraph. In most cases, the ELU must receive (and acknowledge) a second message from the DCP before it acts upon the contents of the first. This procedure is referred to as a "double handshake".

The DCP transmits according to a set of rules which determine the radio site and channel (A or B) to be used and the number of attempts which are to be made to complete one transaction. The DCP's communications model defines the region of coverage of each remote site transceiver. The area exclusively covered by a given site is referred to as its normal zone, while the areas of overlapping coverage are called fringe zones. The transmission rules differ slightly according to whether the train is located in the mormal or fringe zone of a particular remote site.

If the train was last known to be in the normal coverage zone, the DCP's procedure is as follows:

1. If the last transmission was on Channel A, then use Channel B, and vice versa.

2. Transmit the message. If no reply is received within the wait period, retransmit on the same channel.

3. If there is still no reply, transmit on the second channel. If a reply is received, flag the first channel for possible failure; if no reply, then abandon the transaction.

If the train is in a fringe zone:

1. Select the remote site to whose normal zone the train is closest.

2. Select the channel as in step 1 above.

3. Transmit on the first channel as in step 2 above.

4. If no reply, transmit once on the second channel.

5. If still no reply, select the alternate site, switch to the first channel, and transmit once.

6. If no reply, transmit once on the second channel. If there is still no reply, abandon the transaction.

2.2.4 Train Location

Train location refers to the methods with which LIC presents train tracking data to the human user, i.e., the train dispatcher and chief dispatcher. These methods include the summary lineup, the colour graphics track display, and the train graph. The lineup and colour display are discussed under 2.3 Dispatcher Assist Functions.

The train graph is output by the DCP on a dedicated printer at a rate of one line every five minutes. A single line represents the entire length of the controlled territory. A special character marks the location of each train within the territory. Over a period of time the changing positions of the printed characters will form a graphic indication of the movement of trains in the system. Appendix "E" contains several representative DCP train graphs.

2.3 Dispatcher Assist Functions

This section outlines LIC dispatcher assist functions presently implemented. The functions described are:

1. Automated train sheet manipulation.
2. Colour graphics display of train tracking data.
3. Dispatcher displays and reports.
4. Dispatcher shift change procedure.

Consoles are provided for both train dispatcher and chief dispatcher. The consoles, DEC VT-100 video terminals, provide the means to request reports and displays, to enter and manipulate data, and to transmit train control instructions.

Certain functions available to the train dispatcher are not available to the chief, and vice versa. The chief dispatcher's console, for example, is locked out from all aspects of train control, while the train dispatcher may deactivate a train at the end of its run but cannot delete it from the records.

In addition to the regular alphanumeric keyboard and display, the VT-100 terminal has a numeric keypad and four special function keys labelled PF1 through PF4. Each PF key selects one of four main areas: Displays and Reports; Train Sheet Data Entry; Dispatcher Shift Change; and Train Control. Selection of a particular area causes the screen to display a menu from which a specific function may be chosen. Appendix "G" illustrates the menus which result from use of the first three PF keys. Having chosen a menu, the dispatcher uses the VT-100 "ARROW" keys to move the cursor to the function desired, then presses the RETURN key to invoke the function.

2.3.1 Train Sheet Manipulation

LIC maintains an automatic train sheet for every train in the system. There are two classes of train sheet: provisional and dispatcher-created. The provisional train sheet is created by the HOST for any train which enters LIC territory and for which no corresponding dispatcher information is available. The dispatcher train sheet contains data entered by the train dispatcher or chief dispatcher.

Each train sheet consists of four parts:

1. Supply Data: information describing the train, such as engine and caboose numbers, number of cars loaded and empty, their tonnage, and the ordering time. The information is entered locally by the dispatcher and remotely by the chief dispatcher.

2. Crew Data: a description of the crew(s) working the train, including their names and times on and off duty. Entered locally by the dispatcher and remotely by the chief dispatcher.

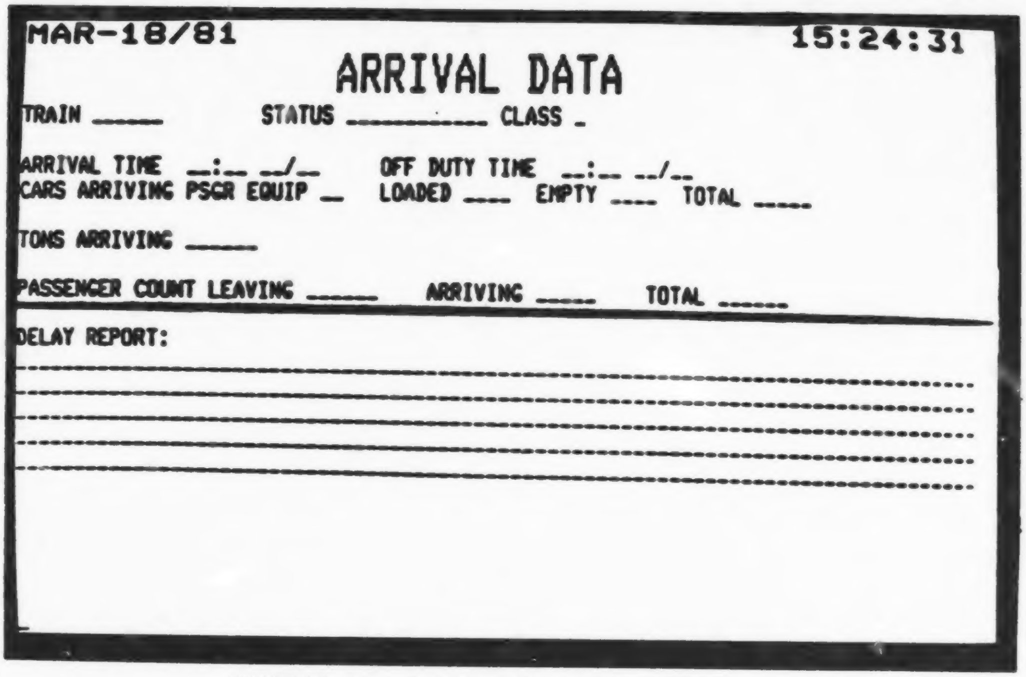
3. Train Performance: lists OS reports accompanied by explanatory remarks. The information is entered automatically by LIC tracking system and manually by the dispatcher.

4. Train Status: information describing the train's operating status. This information is entered automatically by LIC tracking and control systems.

The four parts of any train sheet may be displayed or printed at any time, as may the complete train sheet (see 2.3.3 Dispatcher Displays and Reports).

Creation or modification of a train sheet is carried out from one or other of the dispatcher consoles according to the Train Sheet Data Entry menu (Appendix "G"). The user selects a specific function by means of the VT-100 cursor control keys and then hits RETURN. The system displays a blank or partially completed form such as that shown in Figure 2-16. The number of dashes forming each blank represents the maximum number of characters that may be entered at that point. For example, the six dashes after "TRAIN" indicate that a train identifier of up to six characters may be entered. Wherever possible the blank forms are laid out in the order traditionally followed on the railroad.

The cursor control keys allow the user to move to any desired position on the form at any time. The system performs extensive validation of all operator input and flashes error messages in the appropriate screen area as required. If it is necessary to correct an entry, the user can reposition the cursor and overwrite the original. The user terminates data entry by pressing RETURN, whereupon the system prompts for confirmation before saving or rejecting the entered data.



```
MAR-18/81                                          15:24:31
                         ARRIVAL DATA
TRAIN _____        STATUS __________ CLASS _

ARRIVAL TIME  __:__ __/__     OFF DUTY TIME  __:__ __/__
CARS ARRIVING PSGR EQUIP _   LOADED ___  EMPTY ___  TOTAL ____

TONS ARRIVING _____

PASSENGER COUNT LEAVING _____    ARRIVING ____    TOTAL _____
DELAY REPORT:
```

EXAMPLE OF VT-100 DATA ENTRY SCREEN
(TRAIN ARRIVAL DATA)

FIGURE 2-16

Further details of the LIC automated train sheet function, together with an evaluation of its performance, may be found in section 4.2 of this report.

2.3.2 Colour Graphics Displays

Three colour monitors mounted above the dispatcher's desk (Figure 2-1) provide a graphical representation of the activity in the LIC territory. The information displayed falls into two categories: static data such as track layout, station names, and control points; and dynamic data such as train locations and block status. The static part of the display is refreshed at regular intervals but does not change; the dynamic part is updated continually to reflect data entered by the dispatcher and information reported by the train tracking functions.

The track diagram is spread over three colour display screens. A dispatcher keyboard function allows the three segments of the diagram to be interchanged for convenience. The diagram shows all trackage under LIC control, including sidings, to a resolution of 1/4 mile.

Trackage is displayed in various colours according to occupancy and type of operating authority in effect. An arrowhead symbol indicates the most recently reported location of a train as well as its direction of travel. The train mnemonic, e.g., PR731, appears above the track if the direction is southward and below it if northward. Should communications with a train be lost, the directional arrowhead disappears, and the train mnemonic commences to blink.

Section 4.3 of this report describes the range of LIC colour graphics symbols available at this time and evaluates the performance of the graphics display function.

2.3.3 Dispatcher Displays and Reports

In addition to the Train Graph and Significant Events Report produced by the DCP, a wide range of data displays and printed reports is available via the HOST system Displays and Reports menu (Appendix "G"). The system also prints certain reports automatically either once a day at midnight (Train Sheet Summary and dispatcher Duty Log) or upon completion of a train (full train sheet) before it is deleted from the system.

To view a given display the operator selects the Displays and Reports menu with the VT-100's PF1 key, then moves the cursor to the correct line and presses RETURN. The system will display the data requested on the terminal screen. Should a printed copy of the report be desired, the user positions the cursor at "HARDCOPY" on the appropriate line before hitting RETURN. The full Train Sheet and the Duty Log are available only as hardcopy reports. This menu does not permit any data entry or manipulation.

Further details of the individual displays and reports currently implemented are presented in Section 4.4 of this report.

2.3.4 Shift Change Procedure

In order to protect against unauthorized use of the dispatcher consoles, each dispatcher uses a password to identify himself or herself to the system. Only one such password may be active at any given time; thus when one dispatcher logs off and another logs on the password recognized by the system is changed. In the interim no dispatcher functions are allowed.

The final LIC procedure for dispatcher shift change will consist of four steps, as indicated by the Shift Change menu (Appendix "G"):

1. UPDATE SHIFT TRANSFER: the dispatcher's console displays a copy of the Shift Transfer (Appendix "G"). The outgoing dispatcher may enter any information required to complete the Transfer Notes.

2. SIGN SHIFT TRANSFER: the outgoing dispatcher inters his or her password to approve the transfer. Once this entry has been made no changes are possible, and the system is locked. At this point the system prints a hardcopy Shift Transfer. Both outgoing and incoming dispatchers sign the printed transfer which is retained for the records.

3. LOG OFF DUTY: the outgoing dispatcher logs off, and the password is again required. The system generates an entry in the Duty Log (Appendix "G") at this time.

4. LOG ON DUTY: the incoming dispatcher logs on using his/her password.

At present only the Log On and Log Off functions are implemented (Section 4.4).

3.0 EVALUATION OF TRAIN TRACKING FUNCTIONS

The purpose of this section is to evaluate the LIC System Train Tracking functions. Subsection 3.1 presents an overview of the general criteria established for both Basic and Full Tracking tests. Subsection 3.2 describes the actual tests carried out in compliance with the LIC System Acceptance Test Plans (Appendices "E" and "F"). Subsection 3.3 summarizes the results and conclusions of the Basic Tracking tests, and 3.4 reports the results achieved in the Full Tracking tests. Subsection 3.5 compares the two sets of results and presents an overall evaluation of LIC System performance to date.

3.1 Overview

The LIC Basic Tracking tests, completed in November, 1981, involved six pre-production Engine Logic Units and a single pre-production DCP. The ELU's were installed on three engines and three cabooses which were to be monitored over a period of seven days, i.e., for a total of 42 unit trips. The results of these tests are reported in Section 3.3 below. Upon successful completion of the Basic Tracking tests, B.C. Railway approved Glenayre's ELU design and released it for production of twenty additional units.

The Full Tracking tests were carried out between the middle of August, 1982, and the end of January, 1983. The objective of the Full Tracking tests was to evaluate the train tracking functions under full operational conditions with a single HOST/DCP central computer configuration. At the same time the LIC dispatcher assist features were to be evaluated as described in Section 4 of this report.

For Full Tracking, B.C. Railway equipped a further ten locomotives and ten cabooses with production ELU's. The system was to be shown capable of tracking up to twenty LIC-equipped units or provisional trains on the subdivision at any one time.

Full Tracking performance was to be evaluated against previously established standards for an aggregate period of not less than thirty days of error-free LIC operation, where error-free was defined as a level of operation such that the system met the requirements established in the specification. A further criterion was that operational hours were accrued only when system availability at the control office was 91% or more and when individual vehicles completed at least 96% of a trip error-free. These restrictions were included to avoid undue influence from early installation and equipment problems. The system was evaluated only when operating at an acceptable performance level.

The results of the Full Tracking tests are presented in Section 3.4 below. The test requirements specific to each area of tracking performance are laid out in Section 3.2.

3.2 Train Tracking And Identification Tests

The train tracking and identification tests covered four areas: transponder reporting, odometer calibration, communications coverage, and train location. This section describes the procedure followed in each test, followed by the criteria for successful completion of that test. The evaluation procedures were similar for both Basic and Full Tracking except in the case of Train Location (3.2.4 below).

3.2.1 Transponder Reporting

The DCP events printer records the details of each transponder crossing by unit number and time. This information was retrieved manually and transcribed onto a separate report for each unit. Figure 3-1 is an example of such a report.

The overall mean reporting success rate must exceed 99.8%. The Basic Tracking sample comprised 42 complete unit trips over the subdivision. The Full Tracking criterion was based on a series of samples of 10,000 LIC operational transponder crossing reports, a minimum of four such samples being necessary to satisfy test requirements.

UNIT NO. 710
DATE ________

STATION		MILEAGE	TRANSP. Nº												
N. VANCOUVER		24		F	F	F	F	F	F	F	F	F	F	F	F
AMBLESIDE		30		01	02	03	06	07	09	14	15	16	17	18	19
				N	S	N	S	N	N	S	N	S	N	S	N
MILEAGE		50	0290	X	X	X	X	X	X	X	X	X	X	X	X
		60	0220	X	X	X	X	X	X	X	X	X	X	X	X
			0247	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		100	0046	X	X	X	X	X	X	X	X	X	X	X	X
			0256	X	X	X	X	X	X	X	X	X	X	X	X
HORSESHOE BAY	M	116													
	S		0138												
	A		0279	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		130	0050	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		150													
MILEAGE		165													
BRUNSWICK	A	185													
	M														
	S		0147	X											
	S	200	0231	X											
	M														
	A		0265	[illegible]	[illegible]	X	X	X	X	X	[illegible]	X	[illegible]	X	[illegible]
MILEAGE		230	0054	X	X	X	X	X	X	X	X	X	X	X	X
PORTEAU	A	253	0055	X	X	X	X	X	X	X	X	X	X	X	X
	M		0056	X	X	X	X	X	X	X	X	X	X	X	X
	S		0057												
	S	265	0293												
	M		0059	X	X	X	X	X	X	X	X	X	X	X	X
	A		0060	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		300													
			0249	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		320													

BASIC TRACKING TRANSPONDER REPORT

FIGURE 3-1

3.2.2 Odometer Calibration

The DCP events printer records two items relevant to odometer calibration. First, when the DCP sends a calibrate message to an ELU, it records the unit number and the number and mileage of the transponder at which the unit addressed is to calibrate. Second, the transponder crossing record referred to in Section 3.2.1 contains the engine odometer reading at the transponder. This information was retrieved manually, and for each unit a graph was plotted to show locomotive odometer error versus true subdivision mileage.

The odometer test must also verify that the specified calibration procedure is carried out, as follows:

1. Speak up at first transponder detected.
2. Inference of direction at second transponder.
3. Simple calibration at third transponder at least one mile from the second.
4. In the Full Tracking tests, the system will carry out a full calibration at the next suitable transponder.

In Full Tracking only, if the error at any transponder exceeds 0.05 mile, an automatic simple recalibration must take place. The odometer must be maintained within plus or minus 0.1 mile throughout an entire trip.

3.2.3 Communications Coverage

The DCP software keeps a count of every transmission to and valid response from each active engine or caboose. The events printer reports the total by unit for each five miles of travel as determined by engine odometer or by caboose transponder crossings. These data were extracted manually and recorded on a separate form by unit and trip.

The test requires that the following communications statistics be generated for each trip made by a LIC-equipped vehicle:

1. Total number of transmissions made.
2. Total number of responses.
3. Total number of speakups.

The statistics will be evaluated by location, vehicle, and communications site to pinpoint any areas of poor coverage in which system safety might tend to be degraded.

3.2.4 Train Location

Two methods were used to report train location:

1. The DCP train graph, used in both Basic and Full Tracking tests, provides a printed chart of Unit ID versus mileage at five minute intervals for engines and at control point crossings for cabooses.
2. The HOST system colour graphics tracking display, available only for the Full Tracking tests, provides a continuously updated display of the location and ID of all LIC engines. The display must show the arowhead symbol representing each train in the correct block and at the correct position in the block. Furthermore, the orientation of the symbol must always reflect the last known direction of travel. The location of LIC-equipped units or trains must be reported to within 0.5 mile of the actual location at all times during the test.

The system must correctly specify the locations of LIC units on all possible sections of track.

3.3 Basic Tracking Test Results

The Basic Tracking tests were conducted between October 2 and November 4, 1981. The units initially involved were engines 705, 710, and 717; and cabooses 1871, 1872, and 1875. Engine 717 was withdrawn from service temporarily part way through the tests, and its ELU was transferred to Engine 706. Results are presented for all four engines.

The Basic Tracking test plan stipulated that "the one weeks successful demonstration will be fulfilled after each equipped unit has been tracked for seven (7) consecutive trips over the Squamish Subdivision". It did not prove possible to meet this requirement with all units in a reasonable length of time. A variety of reasons were involved.

Some of the difficulties were quite unrelated to LIC operation. The temporary loss of Engine 717 has been mentioned already. Similarly, the Railway was not always able to retain LIC-equipped cabooses on the Squamish Subdivision, which meant excessive delays between valid trips for tracking purposes.

Problems with the LIC equipment itself meant that many of the trips undertaken were incomplete in terms of the test. In several cases, apparent failure of a caboose logic unit was traced to a power shutdown at the main supply switch. (CLU power was subsequently routed to bypass the switch.) Other caboose equipment problems were not as easily solved.

As a result, the number of successful caboose trips in the Basic Tracking period did not meet the test plan requirements.

Finally, the number of trips and specific trip dates for a given unit are not always the same for every tracking function. This apparent inconsistency arises because the time required for manual extraction of all tracking data from the DCP events record was not available during the test period. In each area of Basic Tracking, however, the total number of trips reported meets or exceeds the total number (6x7=42) stipulated in the test plan.

3.3.1 Transponder Reporting

B.C. Railway conducted the transponder reporting tests and provided the statistical results. If the criterion of 99.8% successful reporting was not met it was to be the responsibility of Glenayre Electronics to determine the reason(s). If the problem could be traced to B.C. Railway's communications system, then the Railway was to assume responsibility. If B.C. Railway was satisfied that any problem discovered could be corrected during the rework phase, then the tests were to be considered complete.

3.3.1.1 Results

Initial tests were carried out with a total of 194 transponders, but the results were not acceptable. Investigation showed that 72 of the transponders had become inoperative, largely as the result of a packaging defect which allowed the ingress of water. The 72 defective transponders were lifted and returned to Glenayre for repackaging. Further tests were conducted with 122 known functional transponders; of these 81 would be encountered on a normal trip from North Vancouver to Lillooet.

Table 3-1 summarizes the results of the Basic Tracking transponder reporting tests. The reporting rate taken over all units and all trips in Basic Tracking was 96.0%. The best record was returned by Engine 705, which successfully reported 99.4% of all transponders encountered.

None of the units met the Test Plan criterion of 99.8% reporting. The overall level of performance is not as good as that observed during the prototype test phase. It should be remembered that the earlier tests were less extensive and were carried out under more closely controlled conditions.

Unit No.	Trips Compltd	Transponders Encountered	Transponders Reported	Transponders Missed	%
705	7	576	573	3	99.4
706	9	534	668	66	91.0
710	12	999	959	40	95.9
717	8	654	647	7	98.9
1871	1	81	78	3	96.2
1872	7	568	560	8	98.5
1875	11	901	851	50	94.4
Total	55	4,513	4,336	177	96.0

TABLE 3-1: BASIC TRACKING TRANSPONDER SUMMARY

3.3.1.2 Problems

Problems traced to defective transponders were solved by redesign of the transponder package. It was felt that the problems which remained were due to shortcomings in the ELU. Accordingly, Glenayre carried out modifications in the following areas:

1. The 27 MHz receiver and baseband data filters.
2. The serial interface device, which was changed from an 8251 to an 8251A.
3. The transponder detection algorithm in the DIGITRAC software, which was altered to take better account of some statistical characteristics of the detection problem.

3.3.1.3 Evaluation

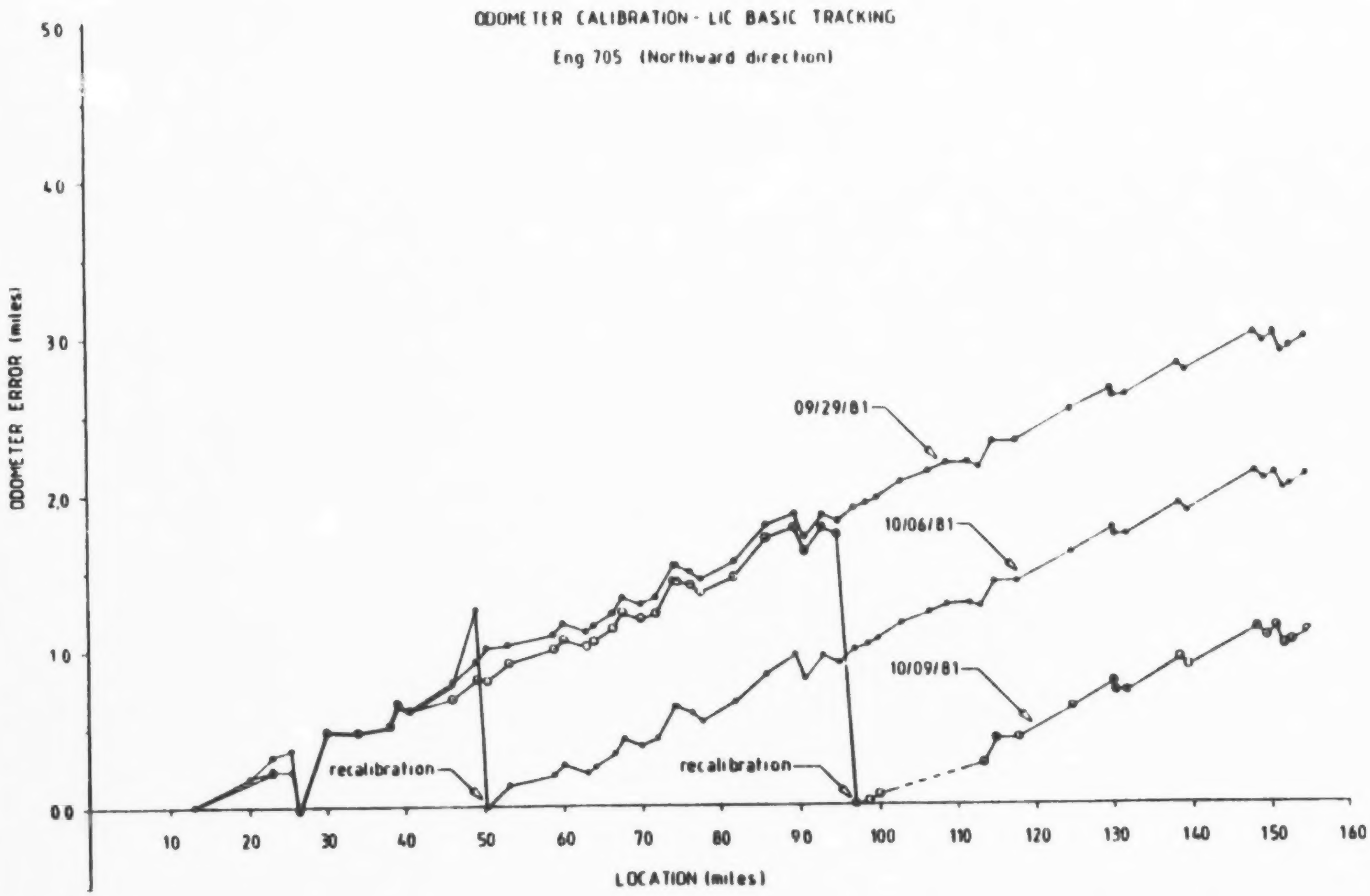
After modifications were made to the DIGITRAC board and software in the ELU, it was decided to proceed to Full Tracking.

3.3.2 Odometer Calibration

The odometer calibration tests were carried out by B.C. Railway, and the resulting DCP events printer records were transcribed and graphed by Railway personnel. In the event of unsatisfactory performance, it was the responsibility of Glenayre Electronics to determine the cause and correct. Additional tests were to be conducted until the calibrate feature proved satisfactory.

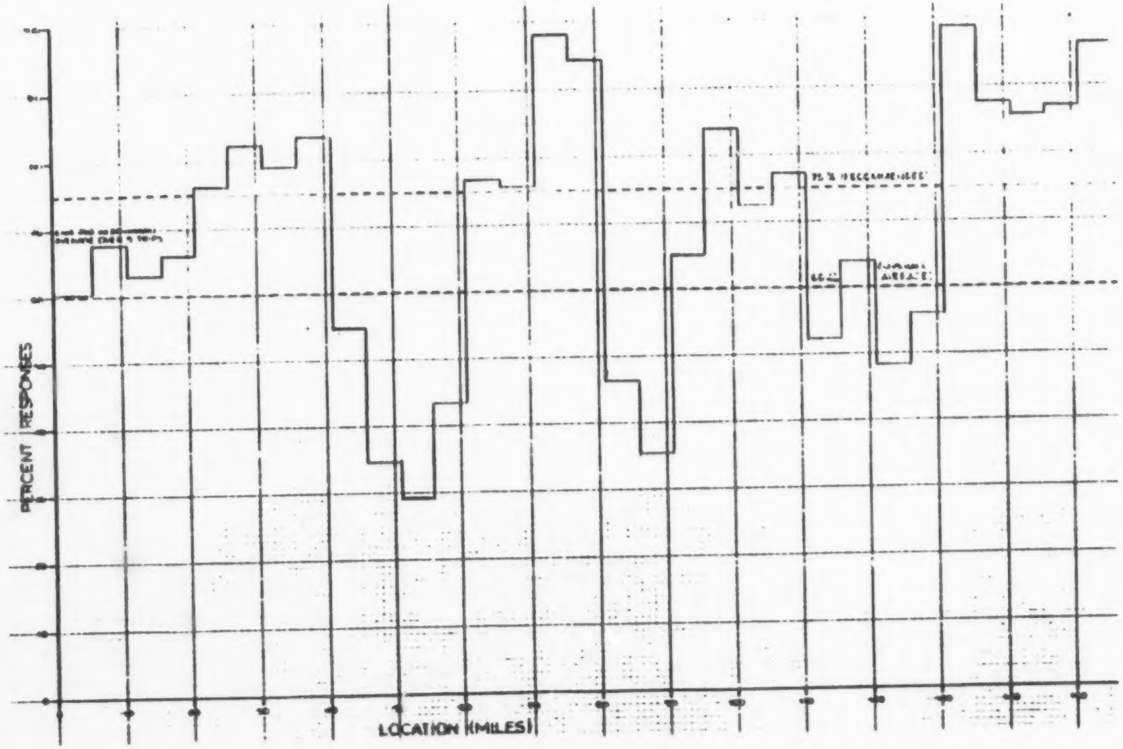
3.3.2.1 Results

The odometer calibration results were plotted as graphs of odometer error versus true mileage. On northward trips, the odometer error was computed as the mileage reported at a transponder crossing minus the true mileage. To maintain uniformity in the graphs the error on southward trips was taken as true minus reported mileage. For odometer calibration purposes, "true" transponder mileage refers to the transponder mileage as stored in the DCP track model. The original calibration records are to be found in Appendix "E". Figure 3-2 is a simple graph for the southward trips made by Engine 705.


ODOMETER CALIBRATION - LIC BASIC TRACKING

Eng 705 (Northward direction)

FIGURE 3-2



COMMUNICATIONS PERFORMANCE - BASIC TRACKING

FIGURE 3-3

3.3.2.2 Problems

Three significant features may be observed in the odometer calibration graphs:

1. The magnitude of the odometer error increased steadily for each unit as it traversed the subdivision. For a given engine the average absolute slope of the graphs is reasonably consistent for both northward and southward trips, but it is not necessarily the same from one unit to the next.

2. All of the graphs show essentially the same deviation at certain locations. For example, the peak at mileage 26.5 occurs on every graph.

3. Some graphs show additional unexplained irregularities, and some show small offsets between lines (not due to recalibration).

3.3.2.3 Evaluation

The odometer calibration feature is potentially a means for accurate determination of train location, but its performance requires further improvement for it to be included in an operational system. It was felt, however, that the problems involved were all understood and would be corrected in short order. Specifically, it was concluded that:

1. Small departures from nominal wheel size on each unit have a significant effect on odometer accuracy. The graphs suggest that a factor to correct for wheel wear can be measured by means of the ELU odometer and applied to subsequent readings to achieve greater accuracy. The results for Engine 706 are particularly interesting. This unit was equipped with new wheelsets at the time of the tests, and the average slope of its calibration plots is near zero. For Full Tracking, the system will use the full calibration procedure which takes the wheel wear factor into account.

2. Closer examination of the lines plotted for a single unit shows that the small departures from the straight line of average slope are not, for the most part, due to random variation or hardware error. Consider, for example, the calibration graphs for Engine 705. Note that the three southward trips produced plots of virtually identical profile. The three northward trips also gave similar profiles, although the lines are offset as the result of recalibration. Moreover, when one graph is inverted and superimposed upon the other, all six lines coincide closely.

   The consistency of these errors could be explained only if the track model locations of certain transponders were incorrect. Upon investigation, it was found that there were errors in the original chaining of the subdivision, which made it necessary either to resurvey all of the trackage or to modify the DCP track model. Given the time and manpower requirements for a full survey, B.C. Railway decided to generate a new track model using the ELU odometer on the V-10 track vehicle to ascertain the actual location of each control point. This work was carried out between June 1 and 11, 1982.

   The accuracy of the V-10's odometer was confirmed by a number of runs over a measured mile, yielding an average value of 1.02 mile. All subsequent readings were corrected by this factor.

   The V-10 then made four complete trips over the Squamish Subdivision, stopping precisely at each control point to record its location on the DCP printer. The mean value for each control point was used in an updated track model.

3. In view of the erratic readings caused by wheelslip or other unknown factors the ELU should be able to do a simple calibration at any transponder when the error in the reported mileage reaches a certain limit.

With the implementation of the changes noted above, it was decided to proceed with Full Tracking.

3.3.2.2 Problems

Three significant features may be observed in the odometer calibration graphs:

1. The magnitude of the odometer error increased steadily for each unit as it traversed the subdivision. For a given engine the average absolute slope of the graphs is reasonably consistent for both northward and southward trips, but it is not necessarily the same from one unit to the next.

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With the implementation of the changes noted above, it was decided to proceed with Full Tracking.

3.3.3 Communications Coverage

B.C. Railway was responsible for conducting the tests and for providing the finished statistical reports. In the event of unsatisfactory communications performance it was also the Railway's responsibility to determine the cause.

3.3.3.1 Results

Table 3-2 summarizes the Basic Tracking communications coverage results. The table shows the average communications performance for each unit (ratio of valid ELU responses received to DCP transmissions made) over the number of trips completed by that unit. Appendix "E" contains the individual trip reports for each unit tested under Basic Tracking.

For the locomotives, trip communications performance ranged from a low of 34% to a high of 78%. In general, however, between half and two-thirds of all message exchanges were successfully completed on a given trip. As was mentioned in the introduction to Section 3.3, it was difficult to get a sufficient number of complete caboose trips during Basic Tracking.

It is not possible at this point to recover the information necessary to report the total number of speakups per trip or to generate individual site coverage statistics for Basic Tracking. Each unit spoke up upon entering LIC territory, but no count of speakups was derived from the DCP record. (Both speakup and site coverage statistics were obtained in the Full Tracking tests.)

Unit No.	Transmissions By DCP	Responses From ELU	Successes Rate (%)
705	12219	8234	67
706	2169	1190	55
710	1504	898	60
717	2015	694	34
Total	17907	11016	61.5

TABLE 3-2: BASIC TRACKING COMMUNICATIONS SUMMARY (ENGINES)

3.3.3.2 Problems

Examination of the trip reports (Appendix "D") suggests that there are certain specific areas of weaker coverage. Figure 3-3 is a graphical representation of typical communications performance by location. The graph shows the percentage of DCP transmissions for which a valid ELU response was received on each five-mile interval of track. The data in this case have been averaged over five northward trips of Engine 710. The chart illustrates clearly the known weak areas at MP 11-20 (Horseshoe Bay), 44-61 (Cheakamus Canyon), 86-94 (Pemberton), and 112-125 (Darcy).

3.3.3.3 Evaluation

The communications coverage results confirm those obtained during the prototype tests, when the observed net success rate was about 60-70%. The theoretical analysis referred to in Section 2.2.3 indicated the need for a somewhat higher level of performance. It was felt, however, that the average reported success rate was adequate for LIC tracking purposes. Additional confirmation came from the system load test (Section "E") in which all six units were placed on one train and tracked successfully through the weak areas.

3.3.4 Train Location

It was the responsibility of the B.C. Railway to gather the DCP train graphs and to monitor the performance of this function. In the event that the train location results were not satisfactory, it was Glenayre's responsibility to determine why and make the necessary corrections.

3.3.4.1 Results

The DCP train graph function performed as specified. Figure 3-4 illustrates a typical DCP train graph.

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3.3.4.1 Results

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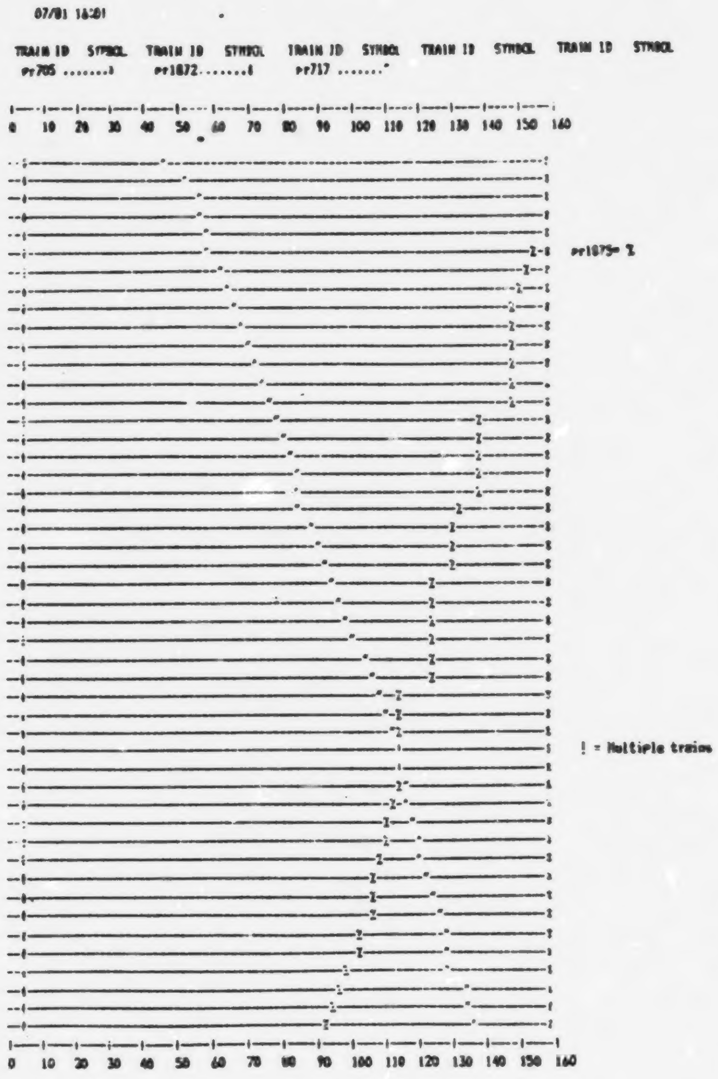


BASIC TRACKING DCP TRAIN GRAPH

FIGURE 3-4

The graph correctly uses a unique symbol, e.g., pr705....*, to identify each unit or Provisional Train. Train locations are shown to the nearest 2 miles. Where more than one train is at approximately the same mileage, a special "multiple trains" symbol is printed. The graph illustrated started at 1601 on October 7, 1981 and shows a meet between PR717 and PR1875 at approximately mileage 114 (Birken).

3.3.4.2 Problems

A certain amount of experimentation was required to select the optimum time interval between printed lines. An interval of five minutes was eventually decided upon. No other problems were encountered with the DCP train location function.

3.3.4.3 Evaluation

The DCP train graph gives a good representation of both current and projected train location. The graphs compare favourably with those produced in CTC systems by means of conventional pen recorder. The advantage of the LIC graph is that it shows both train identification and continuity of the tracking record and thereby eliminates a potential source of confusion.

No modifications to the DCP train location function were found necessary.

3.4 Full Tracking Test Results

The official Full Tracking test period ran from mid-August to last December, 1982; however, statistics in certain areas were accumulated starting in July. The units involved were 3 Budd Cars, 14 freight engines, and 13 cabooses. Table 3-3 lists the B.C. Rail units tested under Full Tracking.

Freight	RDC	Caboose
702	BC-10	1854
703	BC-31	1855
707	BC-33	1858
709		1860
710		1864
712		1865
713		1867
715		1870
716		1875
717		1877
719		1878
720		1879
721		1881
722		

TABLE 3-3: IN FULL TRACKING, B.C. RAILWAY LIC-EQUIPPED UNITS

3.4.1 Transponder Reporting

B.C. Railway gathered the transponder crossing data from the HOST events printer record and transcribed it into a format compatible with that used in Basic Tracking. The records were grouped in samples of 10,000 crossings; five such samples were collected.

Each unit trip record was reviewed, and if any transponders had been missed the cause was investigated. If the problem could be attributed to a known source such as faulty communications or hardware failure, then the record was not included in the sample. The unit(s) involved were withdrawn from LIC testing until the problem was located and corrected.

If the mean reporting success rate over all samples did not exceed 99.8%, then the respective contributions to the deficiency of the DIGITRAC and communications systems were to be evaluated.

3.4.1.1 Results

Table 3-4 summarizes the results of the Full Tracking transponder reporting tests. The mean reporting rate taken over all units and trips included in the five samples was 99.86%. By far the majority of trips were completed without error. Significantly, where performance fell below the required level B.C. Railway personnel were able to determine the cause of the deficiency and, in most cases, to correct the problem (Section 3.4.1.2 below).

Block No. (%)	Transponders Crossed	Transponders Missed	Success Rate
1.	10,000	14	99.86
2.	10,000	15	99.85
3.	10,000	12	99.88
4.	10,000	16	99.84
5.	10,000	11	99.89
TOTALS	50,000	68	99.86

TABLE 3-4: FULL TRACKING TRANSPONDER REPORTING

3.4.1.2 Problems

The Full Tracking tests encompassed far more units and trips than did Basic Tracking, and consequently the number of problems encountered rose substantially. This section relates the most significant problems which arose during Full Tracking.

1. A number of ELU's failed to communicate as a result of parity errors; these errors were found to be caused by hardware failure.
2. Certain transponders which were missed repeatedly were tagged as problem units and were changed out.

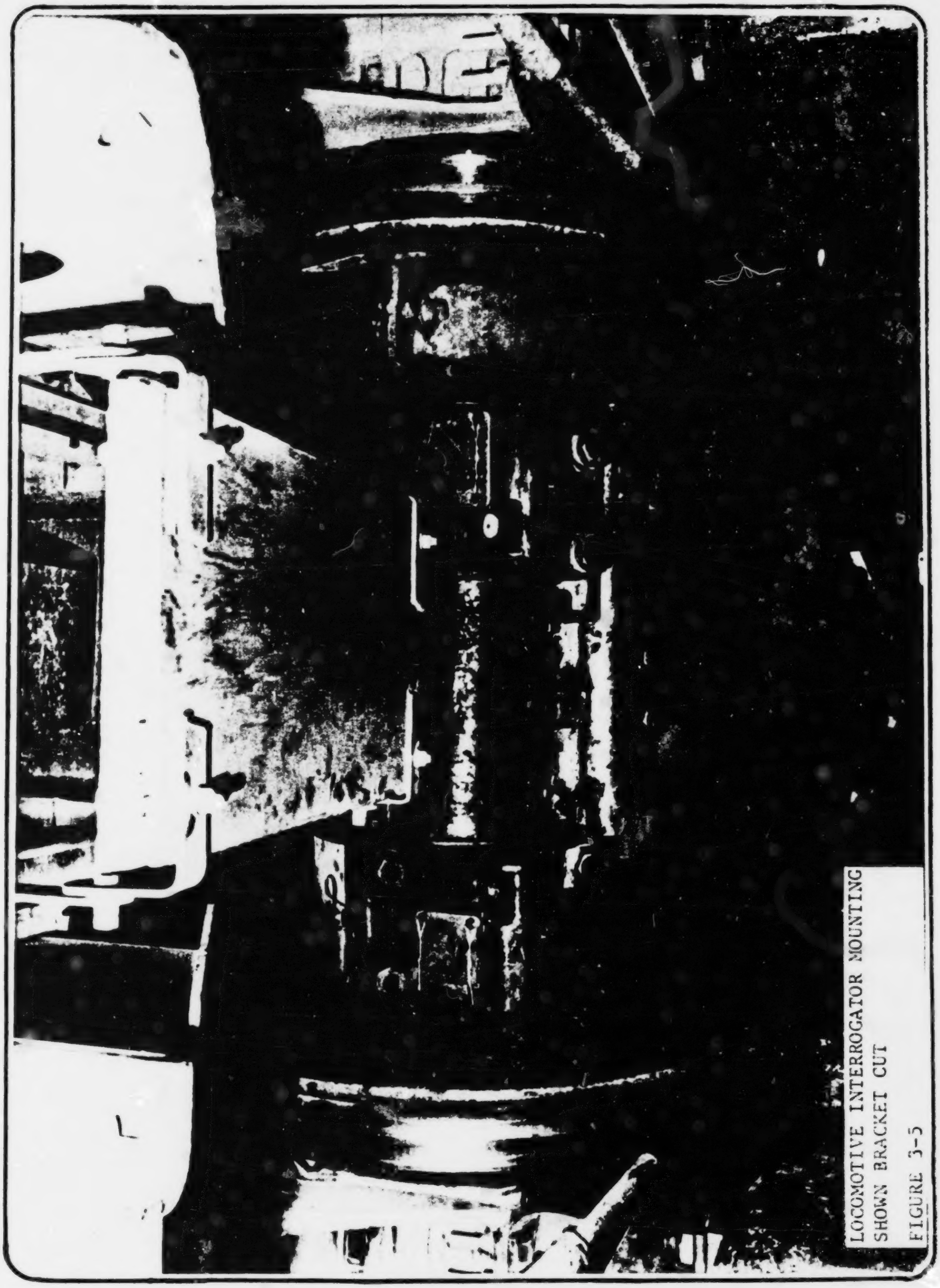
3. The tendency of locomotives to overhang on curves makes the Interrogator mounting position quite critical. In order to standardize the ICU location with respect to the track on all units, B.C. Railway personnel developed a fixture to hold the Interrogator while it was fastened in place. Several ICU's subsequently failed, and the failure was found to be due to excessive current. It was determined that on some engines metal parts adjacent to the ICU were loading the low-frequency RF circuits. The metal mounting bracket, which formed a continuous loop around the ICU, was particularly offensive. The overcurrent problem was solved by cutting a gap in the center of each bracket to eliminate the loop.

4. The final problem was caused by a software malfunction in the HOST computer, which controls all HOST-DCP communications activity. The Full Tracking results were taken from the HOST significant events record rather than from the DCP because the format of the latter was not as easily read. It became apparent, however, that some transponder crossings received by the DCP were not known to the HOST until some time later. Further studies indicated that a lapse of up to 4 minutes could occur between the DCP's reception of transponder record and its appearance on the HOST events printer. This problem is particularly critical in relation to train location.

3.4.1.3 Evaluation

The majority of transponder reporting problems in Full Tracking were caused by hardware malfunction. This fact, together with the excellent performance on non-problem trips, tends to validate the logical design of the relevant software systems.

The software problem referred to above was found to lie not in HOST-DCP communications but in the HOST's handling of the transponder crossing file. A minor program error caused the system to read the second most recent entry in the file rather than the most recent. One result of this error was that a train's route as inferred by the HOST could be in effect one step behind its actual route. The program error was corrected, and the V-10 test was repeated on January 20 and 21, 1983 with complete success.



LOCOMOTIVE INTERROGATOR MOUNTING
SHOWN BRACKET CUT

FIGURE 3-5

The overall transponder reporting success rate achieved in the Full Tracking tests meets the criteria set out in the test plan.

3.4.2 Odometer Calibration

B.C. Railway gathered statistics from the HOST events printer record to verify performance of the calibration procedure specified for tracking-only mode. The calibration procedure comprises the following steps:

1. Speak-up at the first transponder detected.
2. Inference of direction at the second transponder.
3. Simple calibration at the next transponder at least 1 mile from the second.
4. Full calibration at the next suitable transponder.

The LIC System specification prescribes criteria for odometer accuracy, and it was an object of Full Tracking to meet these criteria. The accumulated odometer error must at no time exceed 0.1 mile. If an error of greater than 0.05 mile is detected at a transponder, then an automatic simple recalibration must take place.

3.4.2.1 Results

Evaluation of the odometer in Basic Tracking was hindered by errors in the original track survey which led to invalid transponder locations in the DCP track model. With corrected track model data it was possible to gain a better understanding of the odometer's behaviour. Accuracy improved significantly with introduction of the wheel-wear correction factor. Performance did not consistently meet specification, however, until after the delivery of ELU software version 2.7, which increased the numerical accuracy of the odometer computations. This software version was installed on a few units in December, 1982, but did not come into general use until early January, 1983. For this reason all Full Tracking calibration data recorded prior to January will be ignored in this report.

With the increase in odometer accuracy, B.C. Railway personnel designed a new form on which to record engine performance over the course of a trip. Figures 3-6 and 3-7 are two examples of the new odometer report. Appendix "F-2" contains further results of the Full Tracking calibration tests.

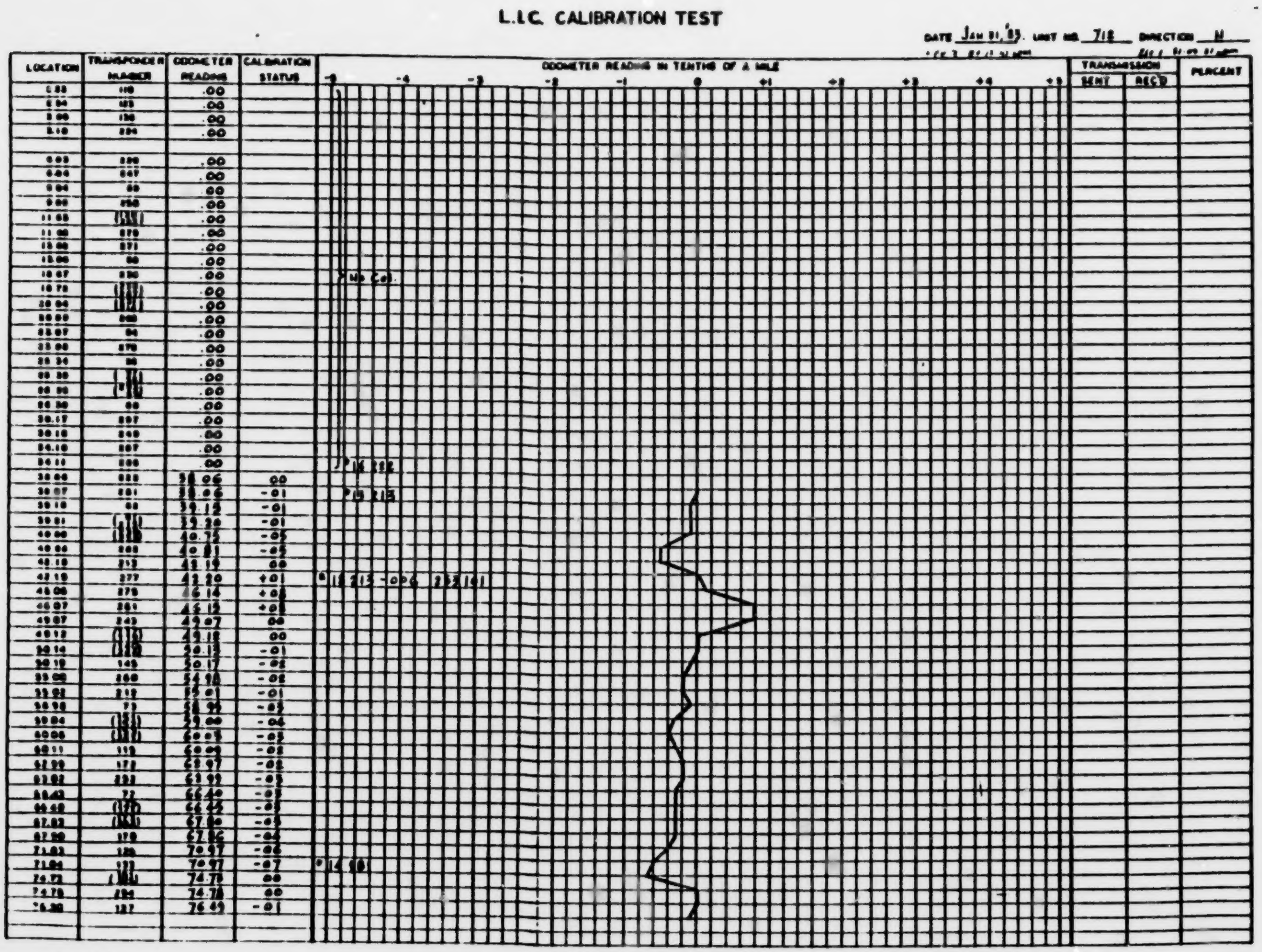
The first point to note concerning the two reports is that one engine (712) remained within specification throughout the trip. The largest difference between odometer and track model mileage is .08 mile. The deviation at MP 46.06 is due to a known chaining error at approximately MP 42. Engine 712 recalibrated five times on the trip (not counting the initial simple calibration). Engine 703, on the other hand, was out of specification on seven occasions and required eight recalibrations.

Apart from the deviation induced by the chaining error at MP 42, the largest odometer errors arose in conjunction with switching moves and meets. Engine 703's large (0.44 mile) error at MP 40.80, for example, occurred after 2 hours and 50 minutes of switching. By contrast engine 713, on the same train, accumulated only 0.04 mile of odometer error in this time. Possible reasons for these errors and for the noticeable difference in performance between units are discussed below.

3.4.2.2 Problems

The ELU odometer is required to compute its own wheel factor based on its recorded distance of travel and the two transponder mileages. For this reason any imprecision in the recorded distance will be reflected in an inaccurate wheel factor. It became evident that with certain values of wheel factor a particular engine could complete a trip with very few odometer readings out of specification. It was expected that a given engine would derive the same or almost the same wheel factor from successive trips, but this behaviour was not always observed.

One possible cause of the variation in computed wheel factor is related to a second observed problem: erratic odometer behaviour at low speeds. The majority of units tested showed very erratic odometer readings at speeds of less than four miles per hour. If an engine travelled at low speed during some part of its full calibration distance, then the resulting wheel factor was almost certain to give rise to odometer errors. Discrepancies were also introduced when a unit was stopped for any length of time, e.g., when waiting for a meet.



L.I.C. CALIBRATION TEST

DATE Jan 31, '83. UNIT NO. 718 DIRECTION N

FIGURE 3-6 (a)

L.I.C. CALIBRATION TEST

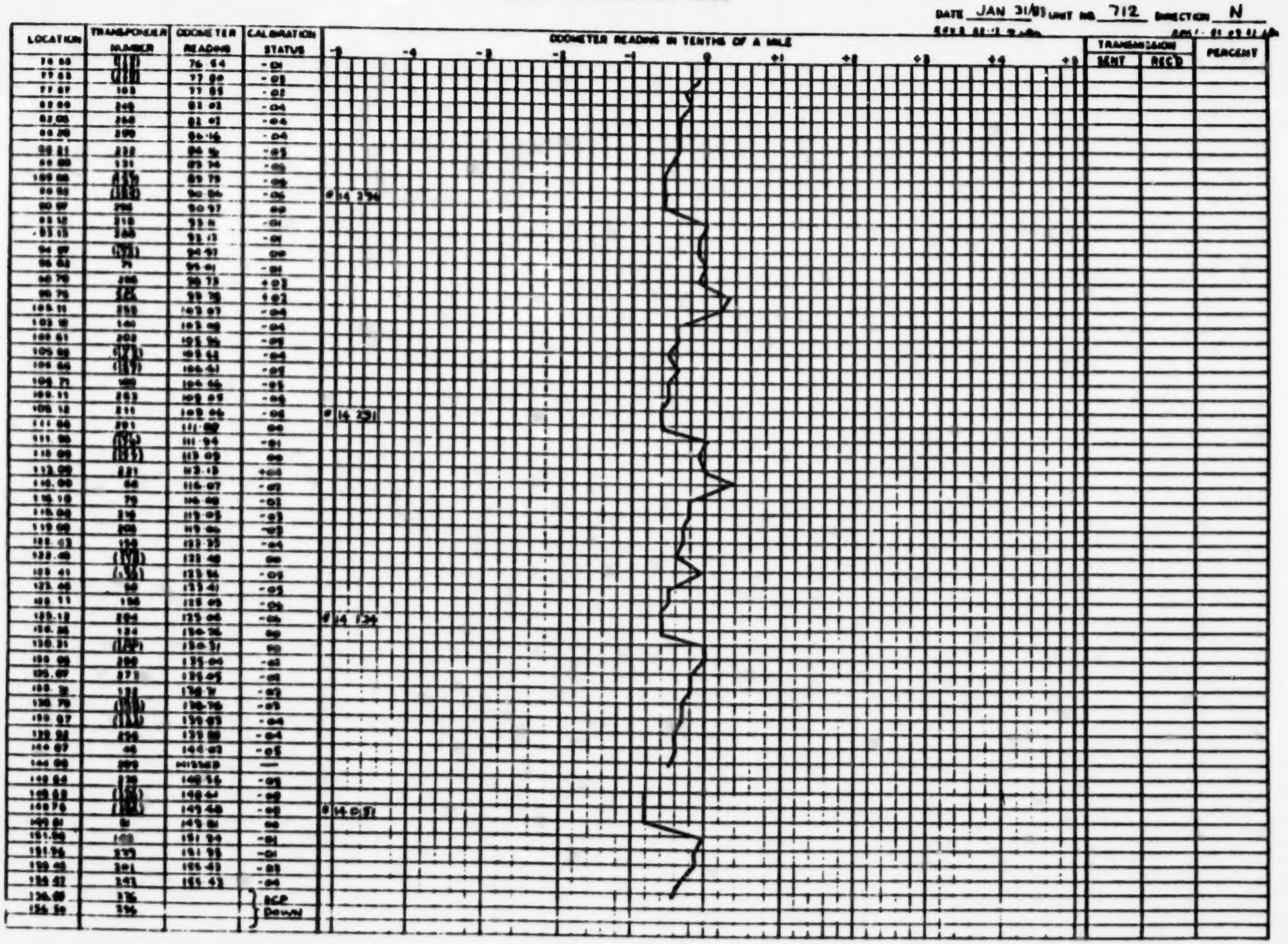
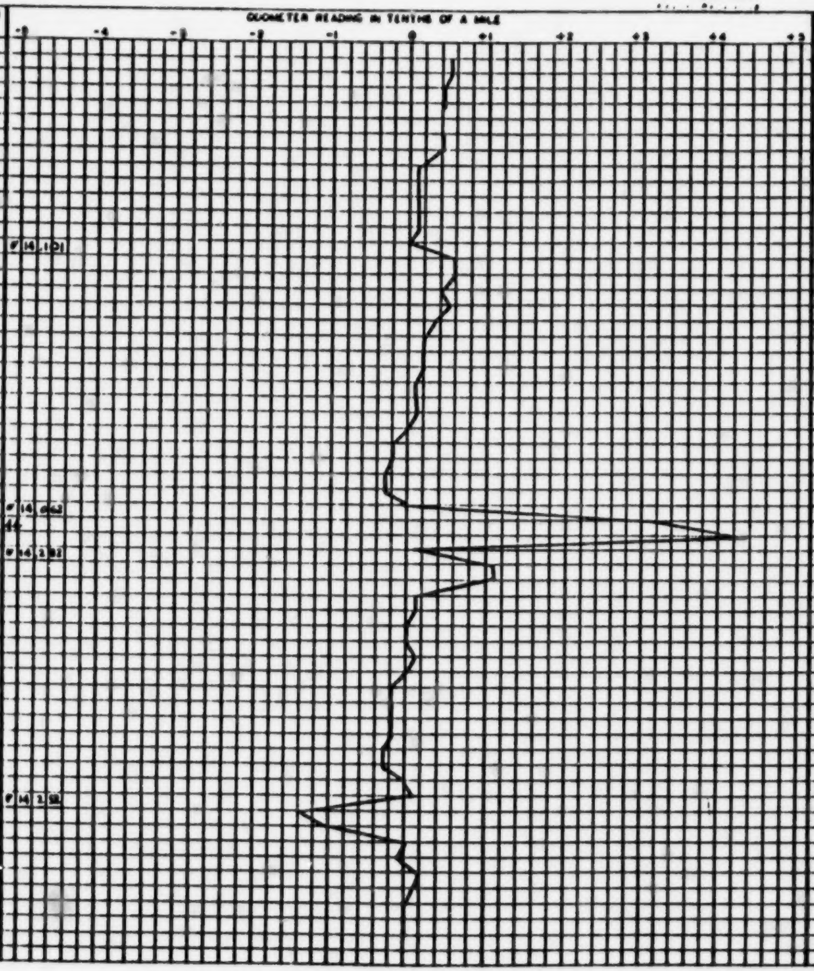


FIGURE 3-6 (b)

L.I.C. CALIBRATION TEST

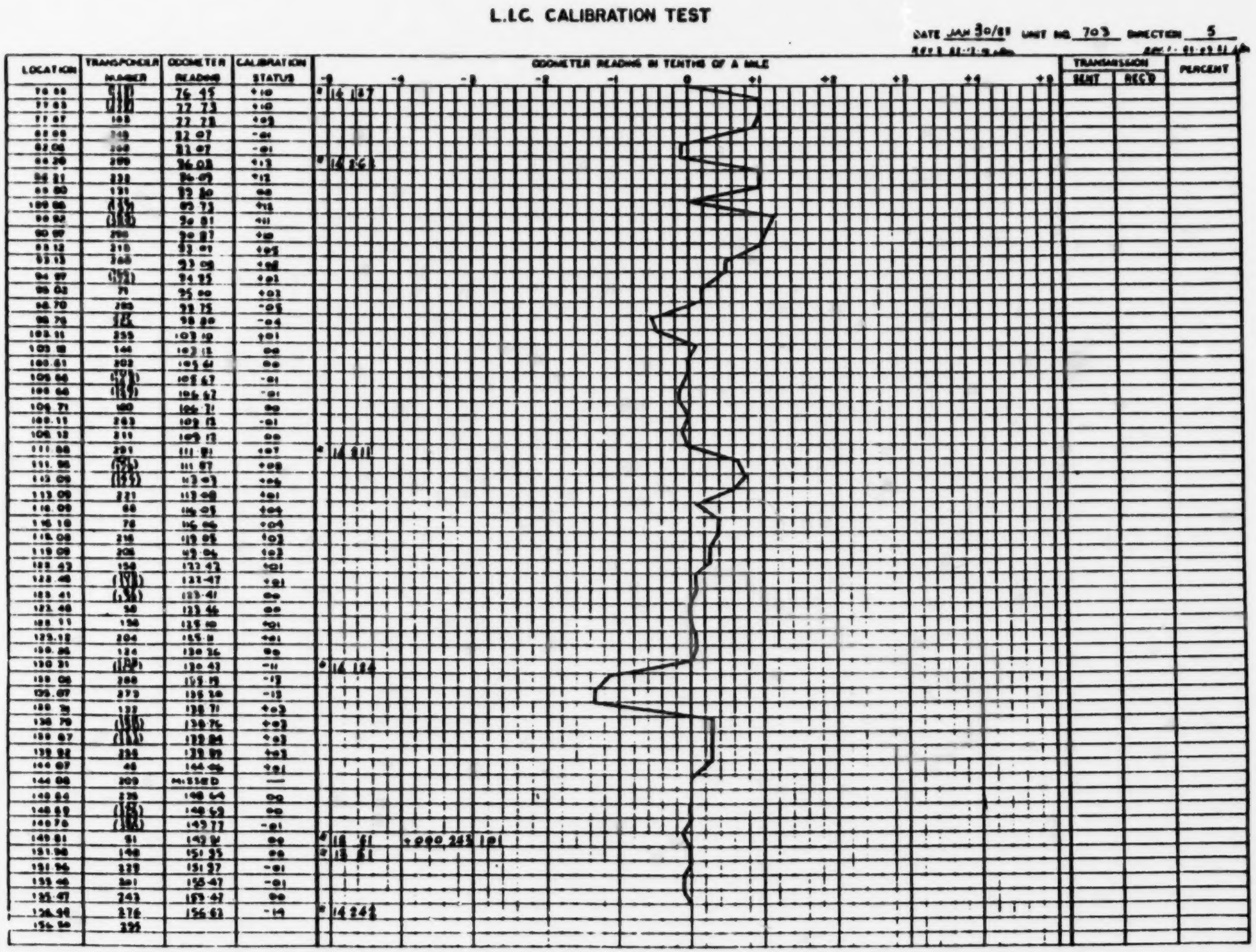
DATE JAN 30/83 UNIT NO 703 DIRECTION S

LOCATION	TRANSPONDER NUMBER	ODOMETER READING	CALIBRATION STATUS
[illegible]	110	2.40	+05
[illegible]	113	2.49	+08
[illegible]	120	3.05	+04
[illegible]	224	3.08	+04
[illegible]	210	5.97	+04
[illegible]	217	6.00	+04
[illegible]	68	9.03	+01
[illegible]	250	9.06	+01
[illegible]	[illegible]	11.62	+01
[illegible]	270	11.67	+01
[illegible]	271	13.01	+01
[illegible]	90	13.06	00
[illegible]	238	18.61	+06
[illegible]	[illegible]	18.66	+06
[illegible]	[illegible]	20.00	+04
[illegible]	266	20.04	+05
[illegible]	94	23.04	+03
[illegible]	278	23.06	+02
[illegible]	96	25.33	+02
[illegible]	[illegible]	25.37	+02
[illegible]	[illegible]	26.33	+01
[illegible]	99	26.73	+01
[illegible]	207	30.16	+01
[illegible]	249	30.18	00
[illegible]	207	34.12	-02
[illegible]	208	34.13	-02
[illegible]	222	38.03	-03
[illegible]	201	38.10	-03
[illegible]	69	39.16	-00
[illegible]	[illegible]	39.90	+31
40.00	[illegible]	40.16/40.33/40.43	-44
40.06	222	40.16/40.57	00
[illegible]	213	43.09	+11
42.19	277	43.08	+11
[illegible]	275	46.05	+01
46.07	261	46.06	+01
49.07	243	49.07	00
49.12	[illegible]	49.12	00
50.14	[illegible]	50.13	+01
50.19	148	50.19	00
55.00	260	55.01	-00
[illegible]	212	55.04	-02
[illegible]	73	57.00	-02
59.04	[illegible]	59.06	-02
[illegible]	[illegible]	60.03	-03
60.11	119	60.14	-03
62.99	173	62.97	00
63.01	231	63.01	+01
[illegible]	72	66.57	-14
[illegible]	[illegible]	66.59	-10
[illegible]	[illegible]	67.03	00
[illegible]	179	67.09	-01
[illegible]	126	71.01	+02
71.04	[illegible]	71.05	+01
74.73	[illegible]	74.73	00
74.78	294	74.78	00
[illegible]	127	76.50	00



TRANSMISSION SENT	TRANSMISSION REC'D	PERCENT

FIGURE 3-7 (a)



L.I.C. CALIBRATION TEST

DATE JAN 30/81 UNIT NO. 703 DIRECTION 5

LOCATION	TRANSPONDER NUMBER	ODOMETER READING	CALIBRATION STATUS
76 00	[illegible]	76 45	+10
77 03	[illegible]	77 73	+10
77 07	103	77 73	+03
82 00	249	82 07	-01
82 06	268	82 07	-01
86 20	299	86 03	+13
86 21	238	86 09	+12
88 80	131	88 80	00
[illegible]	[illegible]	89 73	+12
90 92	[illegible]	90 81	+11
90 97	290	90 87	+10
93 12	210	93 01	+05
93 13	268	93 05	+08
94 97	[illegible]	94 95	+02
95 02	71	95 00	+02
98.70	283	98 75	-05
98 76	[illegible]	98 80	-04
103 11	255	103 10	+01
103 18	144	103 18	00
105.61	202	105 61	00
105 66	[illegible]	105 67	-01
106 66	[illegible]	106 67	-01
106 71	180	106 71	00
109.11	263	109 12	-01
109 12	211	109 12	00
111 88	291	111 81	+07
111. 95	[illegible]	111 87	+08
113 09	[illegible]	113 03	+06
113 09	221	113 08	+01
116. 09	68	116 05	+04
116 10	78	116 06	+04
119.08	216	119 05	+03
119 09	206	119 06	+03
122 42	150	122 41	+01
122 48	[illegible]	122-47	+01
123 41	[illegible]	123-41	00
123 46	50	123 46	00
125 11	150	125 10	+01
125.12	204	125 11	+01
130. 36	124	130 36	00
130 31	[illegible]	130 42	-11
135 06	280	135 19	-13
135.07	273	135 20	-13
138 73	122	138 71	+03
138 79	[illegible]	138-76	+03
139 87	[illegible]	139 84	+03
139 92	234	139 89	+03
144 07	40	144 06	+01
144 08	209	MISSED	—
148 64	235	148 64	00
148 69	[illegible]	148 69	00
149 76	[illegible]	149 77	-01
149 81	91	149 81	00
151.98	148	151 95	00
151 96	229	151 97	-01
153 46	201	153-47	-01
153.47	243	153-47	00
156.49	276	156 63	-14
156 50	295		

ODOMETER READING IN TENTHS OF A MILE
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
14 187
14 263
14 211
14 184
18 61
+000 243 101
13 61
14 248
TRANSMISSION
SENT
REC'D
PERCENT

FIGURE 3-7 (b)

The low-speed odometer behaviour was discovered to be in large measure due to the properties of the General Electric axle generator used on most freight engines. It was found that the amplitude of the General Electric unit's output varied with speed, with the result that at low speeds the pulse stream was lost in electrical noise and the effect on the odometer reading became quite unpredictable. Engine 707 and the RDC's tested were equipped with Q-Tron pulse generators and did not show the same tendency. This was a special application of the Q-Tron generator to B.C. Railway specification, but the cost of adaptation and installation was felt to be excessive for general use.

To combat the low-speed problem, Glenayre developed a circuit which rejects common-mode noise and gives a satisfactory pulse output from the General Electric generator down to less than 0.5 mph. This circuit has been applied to Engine 712 (Figure 3-6) and Engine 713 with excellent results.

3.4.2.3 Evaluation

Odometer calibration did not meet specification in full tracking. This failure is believed to be due to the factors noted above: instability in wheel factor measurement and erratic low-speed behaviour of the General Electric axle generators. The following steps will be taken to correct the problems:

1. Arrangements will be made to allow the DCP to transmit a wheel factor to each locomotive. This procedure means that a factor known to yield accurate readings will be used by the engine odometer at all times.

2. The Glenayre signal conditioning modifications will be installed on all units equipped with General Electric axle generators. The Railway will contact suppliers of this type of equipment concerning their requirements for future installations.

The problems discussed do not affect implementation of LIC Train Control, and this work will be carried on in parallel with the calibration study. The final results of Full Tracking calibration will be included as an appendix with Volume II, Operational Evaluation, Installation and Testing of LIC Train Control.

The problem will never be eliminated on the General Electric axle generators at speeds below .5 MPH. However, by adopting operating/computer procedures which ensure re-calibration whenever a low speed has been experienced, the affects of the General Electric axle generator limitations can be mitigated.

3.4.3 Communications

B.C. Railway generated the following communications statistics for each of the units in service:

1. Total number of transmissions per trip.
2. Total number of responses per trip.
3. Total number of speak-ups per trip.

The results were compiled in various ways to give coverage statistics by location, vehicle, and individual site.

3.4.3.1 Results

As more units were equipped for LIC operation after the conclusion of Basic Tracking, there was a noticeable decline in apparent overall communications performance. In parts of September and October, 1982, the overall communications success rate on any trip for some units was as low as 40%. Several failures among the unit and remote site UHF radio transceivers were also observed at this time.

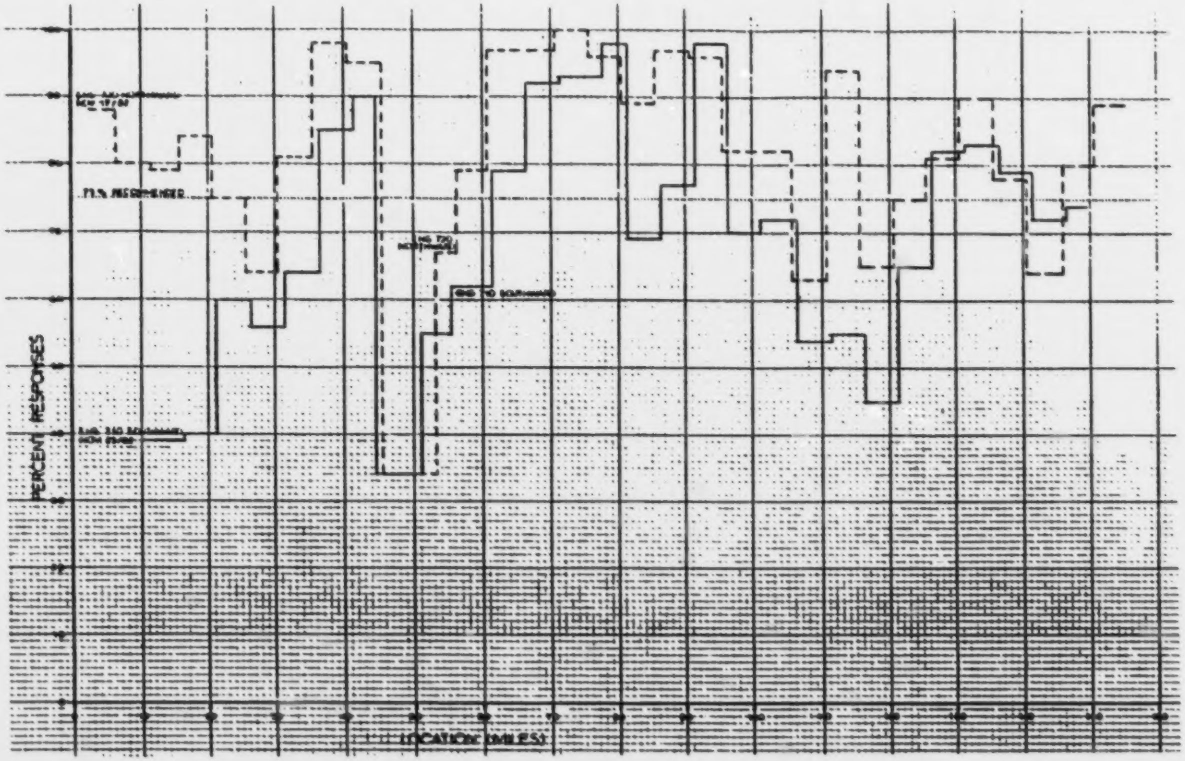
By mid-November a number of changes had been made in different areas, and one result was a dramatic improvement in communications coverage. These changes are outlined in Section 3.4.3.2. Overall communications performance for the majority of units has since remained consistently above 70%, i.e., a valid response is received to approximately three-quarters of all DCP transmission on any given trip.

Table 3-5 summarizes the communications performance of engines and cabooses in the month of December, 1982. The average over all units is 71.7%. Ten engines and three cabooses fall between 70 and 75%, and four more units, two of each type, range from 76 to 80%. Six engines and one caboose show less then 70% responses overall. It may be noted that the preformance level of any one unit is reasonably consistent between trips (see Appendix "F").

Figure 3-8 gives an indication of communications coverage in terms of location along the Subdivision. The graph shows the percentage of valid responses received by the DCP at approximately five-mile intervals on two typical trips in Full Tracking. Note that while there is a considerable difference in overall performance between the two units, the weak areas, particularly Cheakamus Canyon (MP 44-61), are still apparent.

Unit No.	Transmissions By DCP	Responses From ELU	Success Rate (%)
BC-10	26263	18980	72.2
BC-31	2037	1547	75.9
BC-33	5356	4007	74.7
703	1577	920	58
707	10797	7924	73.3
709	6335	5045	79.6
710	8252	6214	75.3
712	9236	6917	74.9
713	10614	7613	71.7
715	9644	6887	71.4
716	10910	7643	70.1
717	9435	6081	64.5
719	5491	3666	66.8
720	4327	3455	79.8
721	4356	3219	73.9
ENGINES	136599	97825	71.6
1858	1787	1450	81
1860	6267	4734	75.5
1875	2934	2091	71.3
1878	5972	4680	78.4
1879	1836	1343	73
1881	8605	5546	64.5
CABOOSES	27401	19844	72.4
OVERALL	164000	117669	71.7

TABLE 3-5: FULL TRACKING COMMUNICATIONS SUMMARY
(DECEMBER, 1982)



TYPICAL COMMUNICATIONS PERFORMANCE - FULL TRACKING

FIGURE 3-8

3.4.3.2 Problems

A variety of communications problems were discovered and corrected in November, 1982, and it is not easy to isolate specific causes and cures. The improvement in performance was due to the combined effect of changes in the following areas:

1. A number of newly-installed ELU's showed problems including invalid identifiers, and these were changed out.
2. Faulty radios found on several units were replaced.
3. Two faulty radios were replaced in remote sites; the fault was thought initially to result from excessive RF from the transmitter on the alternate channel but was later attributed to component failure.
4. As a result of the above problem, all Channel B radios were disabled and the DCP software modified to use only Channel A.
5. A DCP software bug which caused the RSU to timeout and cease transmission under certain conditions was corrected.
6. A number of installation problems such as cabling and remote site antenna tuning were cleared up.

One benefit of reverting to a single channel for ELU-DCP communications is that analysis of future problems will be somewhat simplified.

Communications performance subsequently has shown improvements both in overall success rate and in consistency of results, but the specific geographic areas of poor coverage remain. A detailed study was undertaken with the V-10 track inspection vehicle in January, 1983, to pinpoint these areas.

The coverage problem was found to be most acute where a weak area was also a fringe area, i.e., a location within range of two remote communications sites. The region just north of the Horseshoe Bay tunnel is typical in this respect, as it falls within the fringe area of Watts Point and North Vancouver as defined by the DCP communications model. It was determined that the DCP fringe area site selection algorithm did not always permit successful completion of a transaction, even when communications were possible with one remote site. This failure frequently led to a significant delay before a transaction was completed but did not give rise to an ELU communications failure.

3.4.3.3 Evaluation

The overall communications coverage is considered adequate for purposes of train tracking. The reduced performance in the fringe areas previously identified could lead to problems in Train Control. The weak area at Horseshoe Bay (MP 11-20) should be eliminated when the Watts Point remote site is replaced by one currently under construction on Bowen Island. Various concepts including passive repeaters are being investigated to find the most cost-effective solution for other weak areas, particularly Cheakamus Canyon.

Further studies will be undertaken to determine the need for modifications to either the DCP communications coverage model or the remote site selection algorithm.

3.4.4 Train Location

Two methods of Train Location were tested under Full Tracking: the DCP train graph and the colour graphics tracking display. The train graph had met specification under Basic Tracking, but the subsequent complete redesign of the DCP made it necessary to repeat the test.

The performance of the HOST colour graphics tracking display is discussed in Section 4.3 of this document.

3.4.4.1 Results

The DCP train graph was found to function exactly as it had under Basic Tracking (Section 3.3.4).

3.4.4.2 Evaluation

Train Location by means of the DCP train graph meets specification under Full Tracking; no modifications are considered necessary at this time.

3.5 Comparison of Basic and Full Tracking Performance

This section compares the results achieved in the LIC Basic Tracking tests and Full Tracking tests. Basic Tracking involved three (later four) engines and three cabooses equipped with pre-production LIC electronics. The central computer consisted of a single prototype data collection processor. The test period, nominally seven days, lasted for approximately one month in late 1981.

The Full Tracking tests were a complete evaluation of LIC's Train Tracking and Dispatcher Assist Functions under operational conditions. The central computer system was expanded to include a single HOST processor and a single DCP. The latter was completely redesigned with production hardware and revised software. Ultimately a total of 30 units equipped with production ELU's were monitored between August, 1982, and the end of January, 1983. The remainder of this section compares Basic and Full Tracking results in each of the four tracking functions.

3.5.1 Transponder Reporting

The criterion established for both tests was that units must sucessfully report at least 99.8% of all transponders crossed. The Basic Tracking samples was based on a total of 42 unit trips, and of a total of approximately 3,400 transponder crossings only 96.0% were reported correctly. Transponder reporting under basic tracking therefore, did not meet specification.

Between Basic and Full Tracking, several changes were made to the ELU hardware, and the transponder detection algorithm was modified. Under Full Tracking the transponder reporting success rate was 99.86%, over a total of 50,000 operational transponder crossings. It was therefore confirmed that LIC transponder reporting meets specification.

3.5.2 Odometer Calibration

Under Basic Tracking units recalibrated only on loss of communications or after recovery from a system crash; no full calibration was performed. The calibrations results clearly demonstrated the existence of two problems: (a) the need for an accurate wheel-wear correction factor, and (b) the presence of errors in chaining and in the DCP track model. Both of these problems were addressed in the rework period between test phases.

The acceptance test plan for Full Tracking laid down criteria for odometer accuracy mile. By the conclusion of the Full Tracking test period it was apparent that odometer calibration would not meet the specification of less than 0.1 mile error at all times. Performance is considerably better than under Basic Tracking, but two areas require further study: wheel factor stability and low-speed performance.

3.5.3 Communications Coverage

Under Basic Tracking less than 62% of all DCP transmissions, on average, were successfully acknowledged. Analysis of the data by location identified several geographical areas of poor radio coverage.

Under Full Tracking the communications success rate has risen to almost 72% overall, with some units showing as high as 80% over a complete trip. The increase does not reflect any significant changes to the communications system but is rather in line with general improvements in all aspects of the LIC System. The same areas of weak coverage, e.g., Cheakamus Canyon, may be found in the later results. The Railway intends to investigate means such as passive repeaters to enhance signal coverage of the weak areas.

3.5.4 Train Location

Under Basic Tracking the only graphical means of train location was a time-distance plot produced on a dedicated printer by the DCP. This function was found to perform correctly from the outset, requiring only minor adjustments to the rate of printing. Re-design of the DCP for Full Tracking made it necessary to repeat the test of the train graph, and it again met specification.

The most significant innovation in Full Tracking train location was the HOST graphics display which shows a scale representation of the entire LIC territory on three colour monitors above the dispatcher's desk. The HOST graphics display meets the requirements for train location in tracking-only mode; however, its treatment of control-point crossings is not sufficiently accurate for train control.

3.5.5 Final Evaluation

LIC is a complex system of many interacting components. A deficiency in one area may give rise to problems which mask or obscure faults in another. LIC tracking functions met specification for train tracking in all areas except odometer calibration, but the problems which remain are straightforward and appear amenable to solution. The same statement could not have been made a year earlier.

4.0 EVALUATION OF DISPATCHER ASSIST FUNCTIONS

The purpose of this section is to evaluate the dispatcher assist functions as implemented in the HOST computer for Full Tracking. Section 4.1 is an overview of the evaluation procedure. Sections 4.2 through 4.5 discuss system performance in four areas: train sheet manipulation; colour graphics displays; dispatcher displays and reports; and shift change procedure. Section 4.6 is an overall evaluation of the LIC dispatcher interface.

4.1 Overview

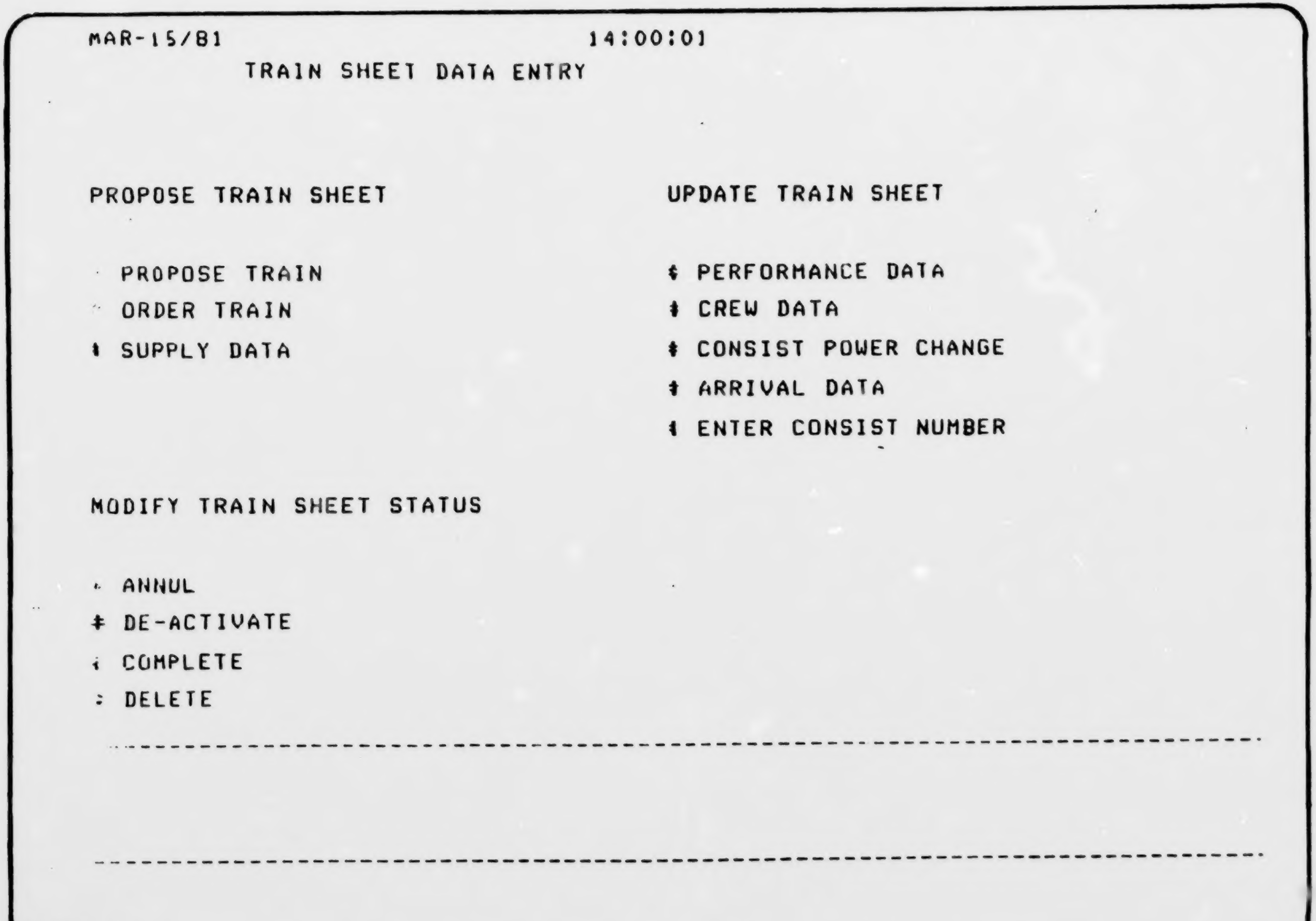
Evaluation of the LIC Dispatcher Assist functions was carried out by a B.C. Railway Chief Dispatcher specially assigned to the task. As mentioned in Section 2.3, the dispatcher interface uses CRT terminal menus as the means to select a desired operation. The operations available fall into two classes: those which involve data entry and those which print or display pertinent information. Tests of the dispatcher interface took three forms, depending on the type of operation under test.

First, all possible menus were exercised to ensure that they were logically consistent and that the correct operation was selected via each menu item. Second, the data entry functions were exhaustively tested to ensure that each data field would accept only data of the correct format and length, and that invalid or extraneous characters would be rejected. In addition, it was necessary to confirm that data entered in connection with one operation would be available when required by another operation. Third, all of the dispatcher displays, reports, and logs were requested and examined for correctness. Finally, since certain functions are accessible only to the train dispatcher and others only to the chief, steps were taken to confirm that the proper restrictions were in effect.

The remainder of this section describes the menus, displays, and reports which were implemented for the Full Tracking tests.

4.2 Train Sheet Manipulation

The Train Sheet Data Entry menu (Figure 4-1) shows LIC train sheet manipulation to be divided into three functional areas:



```
MAR-15/81                       14:00:01
          TRAIN SHEET DATA ENTRY


PROPOSE TRAIN SHEET                    UPDATE TRAIN SHEET

  PROPOSE TRAIN                        ‡ PERFORMANCE DATA
  ORDER TRAIN                          ‡ CREW DATA
‡ SUPPLY DATA                          ‡ CONSIST POWER CHANGE
                                       ‡ ARRIVAL DATA
                                       ‡ ENTER CONSIST NUMBER


MODIFY TRAIN SHEET STATUS

  ANNUL
‡ DE-ACTIVATE
; COMPLETE
: DELETE
 ----------------------------------------------------------------



----------------------------------------------------------------
```

FIGURE 4-1

1. PROPOSE TRAIN SHEET: allows the dispatcher to enter information necessary to describe a train which is to be operated.

2. UPDATE TRAIN SHEET: allows entry of further descriptive information such as crew data and information related to the actual operation of the train, e.g., notes on train performance data.

3. MODIFY TRAIN SHEET STATUS: allows the dispatcher to make certain changes to the status of a train sheet.

Every LIC train sheet is assigned a certain status which may be changed manually as a result of data entry or direct dispatcher modification, or automatically as a result of events detected by the system. The status of a dispatcher train sheet will fall into one of the following categories:

1. Proposed: basic information about the train has been entered.

2. Called: the crew call time has been entered.

3. Active: the train is currently in LIC territory and is being polled.

4. Deactivated: the train has arrived at its destination and holds no authorities to occupy.

5. Annulled: the train has never been active and will not run.

6. Completed: all train sheet information has been entered and the final full train sheet has been printed.

Certain train sheet manipulation functions may be carried out by both the train dispatcher and the chief dispatcher, while some are accessible to only one of the two employees. Table 4-1 summarizes the operations which may be performed, who may perform them, and the resulting train sheet status.

FUNCTION	PERFORMED BY	PREREQUISITE STATUS	RESULTING STATUS	NOTES
DATA ENTRY				
Propose	Chief Dispatcher	None	Proposed	
Supply Data	Dispatcher	Proposed	No Change	Information Entry Only
Order	Dispatcher/ Chief Dispatcher	Proposed	Ordered	
Call Crew	Dispatcher/ (Other User–Future)	Proposed/Ordered	No Change	
Change Supply Data	Dispatcher	Proposed/Ordered/ Active	No Change	
Performance Data	Dispatcher	Active/ Deactivated	No Change	Information Entry Only
Arrival Data	Dispatcher	Active/ Deactivated	No Change	
Consist #	Dispatcher	Proposed/Ordered/ Active	No Change	Information Entry Only
STATUS CHANGE				
Activate	Engineman(ACK Button)/ Speakup/Authority Issued	Proposed/Ordered	Active	
Deactivate	System/ Dispatcher	Active/Annulled Ordered/Proposed	Deactivated	
Annul	Dispatcher/ Chief Dispatcher*	Proposed/Ordered	Annulled	
Complete	Dispatcher anc Chief Dispatcher	Deactivated	Dispatcher/ Chief Dispatcher Completed	No Further Entry Allowed
Delete	Chief Dispatcher	Deactivated/ Annulled	Deleted	Summary Report Must Be Completed

* By Chief Dispatcher only if status is "Proposed".

TRAIN SHEET FLOW CHART

TABLE 4-1

4.2.1 Propose Train Sheet

This function allows the dispatcher to enter information related to the basic features of the train. The Train Sheet Data Entry menu shows three headings under which this information is entered, as follows:

PROPOSE TRAIN allows entry of:

1. Train identification code (defaults to last train referenced).
2. Train sheet status (Proposed or Called - determined by system).
3. Class (Freight, Passenger, Other).
4. Train message (free form text which typically describes the work to be performed by the train).
5. Originating station or control point.
6. Destination station or control point.
7. Turn point station or control point (if applicable).
8. Estimated time and date of departure from originating station.
9. Estimated time and date of departure from turn point (if applicable).

ORDER TRAIN allows entry of the ordering time, together with the supply data listed below:

SUPPLY DATA allows entry of:

1. Identification of lead engine.
2. Operating characteristics of lead engine (e.g., percent full power).
3. Consist power (identification and operating characteristics of up to 15 additional engines).
4. End-of-train unit identification.
5. Deadhead cabooses (up to 3 additional caboose identifiers).

6. Number of passenger cars leaving originating station.

7. Number of loaded freight cars leaving originating station.

8. Number of empty freight cars leaving originating system.

9. Total number of cars leaving originating station.

10. Tonnage of train leaving originating station.

11. Length of train (feet).

12. "A"-rating of total consist power over ruling grade of the route (calculated by the system).

13. Tonnage of train to travel over the ruling grade.

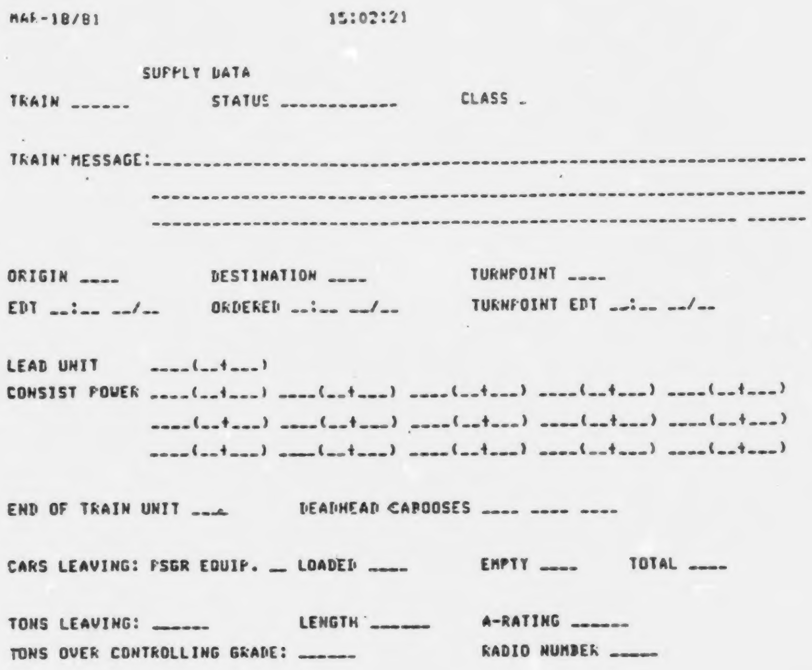
14. Portable radio numbers assigned to the train.

Figure 4-2 illustrates the menu used for entry of all of the data described in Section 4.2.1.

4.2.2 Update Train Sheet

Once a train has been proposed or ordered the train sheet data may be updated at any time. In certain cases the train sheet status must be Active before valid data may be entered. This section of the Train Sheet Data Entry menu offers a selection of five functions, each of which permits modification of a particular part of the train sheet:

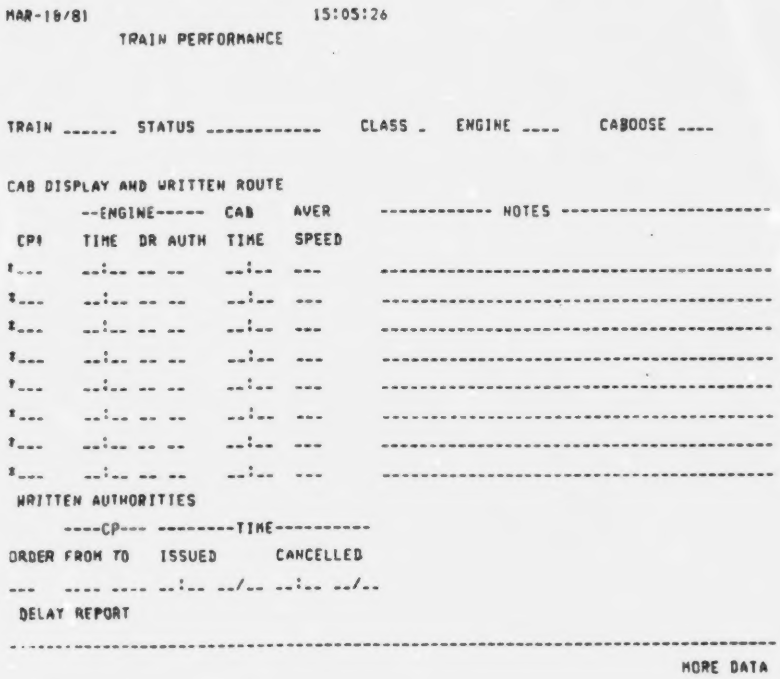
1. PERFORMANCE DATA allows the dispatcher to enter comments concerning control point crossings for LIC-equipped trains. Upon selection of this function the system presents the display shown in Figure 4-3. The dispatcher can enter free form text on any line under the heading NOTES.



```
MAR-18/81                    15:02:21

            SUPPLY DATA
TRAIN ------        STATUS ------------       CLASS -

TRAIN MESSAGE:------------------------------------------------------------
              ------------------------------------------------------------
              ----------------------------------------------------- ------

ORIGIN ----         DESTINATION ----          TURNPOINT ----
EDT --:-- --/--     ORDERED --:-- --/--       TURNPOINT EDT --:-- --/--

LEAD UNIT      ----(--+---)
CONSIST POWER ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
              ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
              ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)

END OF TRAIN UNIT ---       DEADHEAD CABOOSES ---- ---- ----

CARS LEAVING: PSGR EQUIP. _ LOADED ----       EMPTY ----    TOTAL ----

TONS LEAVING: ------        LENGTH ------     A-RATING ------
TONS OVER CONTROLLING GRADE: ------           RADIO NUMBER -----
```

SUPPLY DATA ENTRY FORM

FIGURE 4-2



```
MAR-10/81                       15:05:26
              TRAIN PERFORMANCE


TRAIN ______  STATUS ____________    CLASS _  ENGINE ____    CABOOSE ____

CAB DISPLAY AND WRITTEN ROUTE
        --ENGINE-----  CAB    AVER     ------------ NOTES ----------------------
 CP#    TIME  DR AUTH  TIME   SPEED
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
#___    __:__ __ __    __:__  ___      __________________________________________
 WRITTEN AUTHORITIES
      ----CP--- --------TIME----------
ORDER FROM TO   ISSUED      CANCELLED
___   ____ ____ __:__ __/__ __:__ __/__
 DELAY REPORT
---------------------------------------------------------------------------------
                                                                        MORE DATA
```

PERFORMANCE DATA ENTRY FORM

FIGURE 4-3

The display is headed by the following identifying information:

(a) Train identification.

(b) Current train status.

(c) Lead engine identification.

(d) End-of-train unit identification.

The next part of the display contains control point crossing information, which includes:

(a) Control point identification.

(b) Time engine crossed control point.

(c) Direction of travel.

(d) Time caboose cleared the control point.

(e) Average speed through the previous block.

2. CREW DATA allows entry of data describing the crew or crews which will operate the train. Upon entry of the train identification, the system displays the screen shown in Figure 4-4 and prompts for the following data:

(a) Crew number (assigned by the system).

(b) Conductor name.

(c) Engineman name.

(d) Trainman 1 name.

(e) Trainman 2 name.

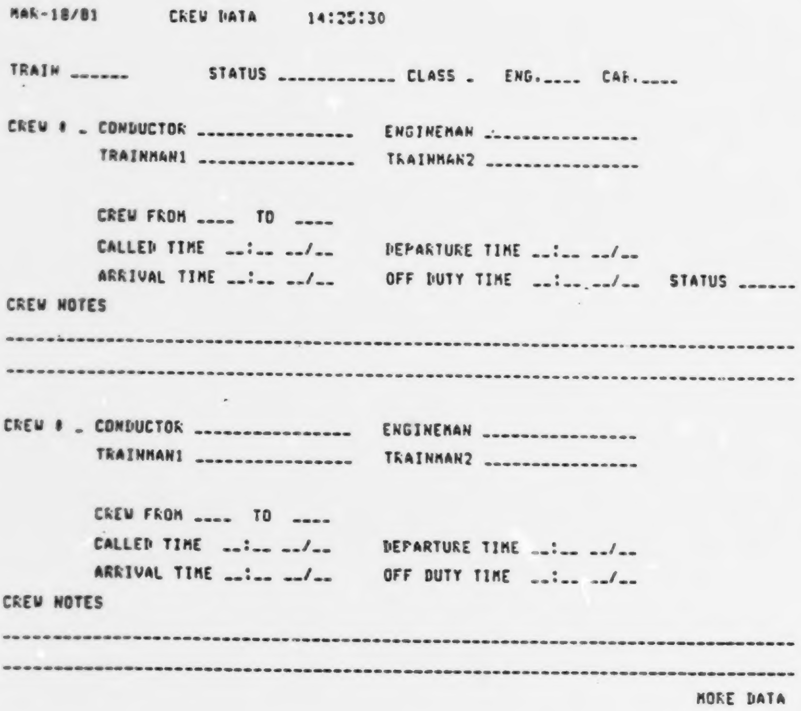
(f) Originating station of crew.

(g) Destination station for crew.

(h) Call time and date (defaults to current date - c/s (Continuous Service) may be entered instead).

(i) Time and date of departure from originating station.

(j) Time and date of arrival at destination station.



```
MAR-18/81       CREW DATA     14:25:30

TRAIN ______        STATUS ____________ CLASS _  ENG.____  CAR.____

CREW # _ CONDUCTOR ________________   ENGINEMAN _______________
         TRAINMAN1 ________________   TRAINMAN2 _______________

         CREW FROM ____  TO  ____
         CALLED TIME  __:__ __/__     DEPARTURE TIME __:__ __/__
         ARRIVAL TIME __:__ __/__     OFF DUTY TIME  __:__ __/__   STATUS ______
CREW NOTES
------------------------------------------------------------------------------
------------------------------------------------------------------------------

CREW # _ CONDUCTOR ________________   ENGINEMAN _______________
         TRAINMAN1 ________________   TRAINMAN2 _______________

         CREW FROM ____  TO  ____
         CALLED TIME  __:__ __/__     DEPARTURE TIME __:__ __/__
         ARRIVAL TIME __:__ __/__     OFF DUTY TIME  __:__ __/__
CREW NOTES
------------------------------------------------------------------------------
------------------------------------------------------------------------------
                                                                     MORE DATA
```

CREW DATA ENTRY FORM

FIGURE 4-4

(k) Time and date off duty (c/s may be entered).

(l) Crew status.

The system will accept data for up to six crews for any one train.

3. CONSIST POWER CHANGE allows the dispatcher to enter information on each unit in the train's consist. Figure 4-5 shows the Consist Power Change display, which is headed by the following identifying data:

(a) Train identification.

(b) Train status.

(c) Class of train.

(d) Current location (mileage) from ELU data.

(e) Current speed from ELU speed data.

The system prompts for information on each unit in the consist. Data for up to 16 units may be entered; the lead unit is Unit number 1. The information which may be entered or changed for each unit comprises the following items:

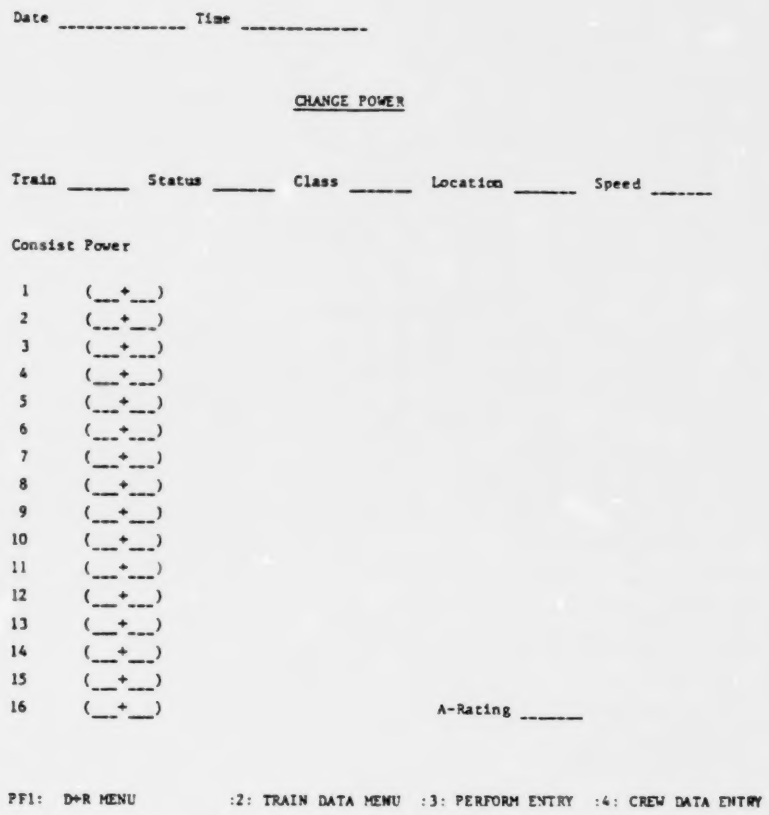
(a) Unit number.

(b) Power rating, which may be either a number (percentage) in the range 01-99 or one of: ID (idling deadhead), FP (full power), or DD (dead and drained).

(c) Control point at which unit is to be picked up or set out.

Any changes to the consist data will cause the system to generate a Power Report containing the above data plus dispatcher's comments.

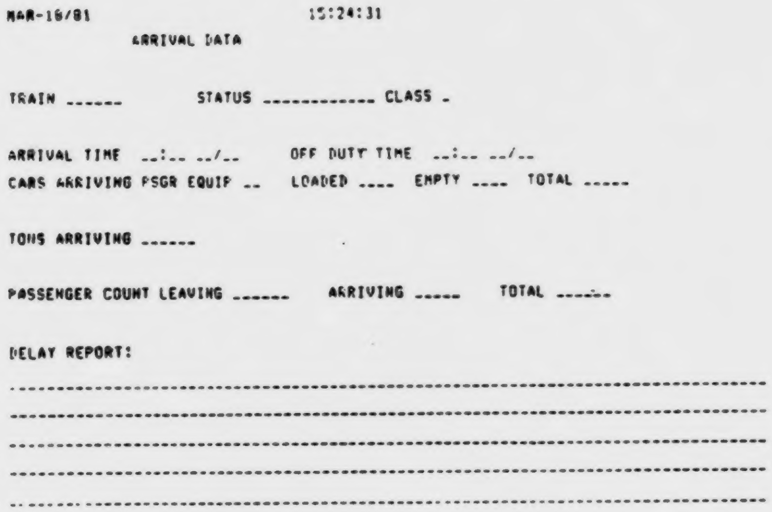
4. ARRIVAL DATA allows entry of information related to the arrival of the specified train at its destination, using the display format shown in Figure 4-6. The system displays the train identification and the status and class of train, then prompts the dispatcher for the following data:



```
Date _____________ Time _____________

                         CHANGE POWER

Train ______  Status ______  Class ______  Location ______  Speed ______

Consist Power

  1      (___+___)
  2      (___+___)
  3      (___+___)
  4      (___+___)
  5      (___+___)
  6      (___+___)
  7      (___+___)
  8      (___+___)
  9      (___+___)
 10      (___+___)
 11      (___+___)
 12      (___+___)
 13      (___+___)
 14      (___+___)
 15      (___+___)
 16      (___+___)                    A-Rating ______

PF1:  D+R MENU        :2: TRAIN DATA MENU  :3: PERFORM ENTRY  :4: CREW DATA ENTRY
```

CONSIST POWER CHANGE

FIGURE 4-5



```
MAR-16/81                      15:24:31
          ARRIVAL DATA

TRAIN ------        STATUS ------------ CLASS -

ARRIVAL TIME  --:-- --/--     OFF DUTY TIME  --:-- --/--
CARS ARRIVING PSGR EQUIP --   LOADED ----  EMPTY ----  TOTAL -----

TONS ARRIVING ------

PASSENGER COUNT LEAVING ------    ARRIVING -----    TOTAL ------

DELAY REPORT:
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
```

DATA ENTRY FORM FOR ARRIVAL DATA

FIGURE 4-6

(a) Time and date of arrival at destination.

(b) Off duty time and date for crew (which changes the crew status from ACTIVE to FINISH).

(c) Number of cars on arrival (passenger, loads, empties, total cars).

(d) Tonnage of train on arrival.

(e) Number of passengers (leaving originating station, arriving at destination, and total passengers handled).

Finally, the dispatcher may enter a free-form delay report to complete the arrival data.

5. ENTER CONSIST NUMBER causes no display of data, but simply allows entry of the consist number of a train.

4.2.3 Modify Train Sheet Status

This function allows the dispatcher or chief dispatcher to change the status of a train sheet. Upon selection of this function the system prompts for the identification of the train whose status is to be modified. The change is effected by selection of one of the four items listed:

1. ANNUL

2. DE-ACTIVATE

3. COMPLETE

4. DELETE

4.2.4 Problems

The dispatcher was able to create and manipulate train sheets according to specification, but difficulties arose in the association and disassociation of operating units with train sheets.

Upon entry into LIC territory a unit speaks up, and the HOST creates a provisional train sheet. If the system contains a dispatcher-created train sheet which lists that unit, then it should associate the unit with the dispatcher train sheet and delete the provisional. Among other things, this association allows units other than the lead engine and end-of-train units to be placed in a quiescent polling condition.

In order for the system to search the dispatcher train sheet for a unit, the train sheet status must be ACTIVE. The train sheet cannot become active, however, until the dispatcher has issued an ACK WHEN READY request and the engineman has pressed his ACKNOWLEDGE button in response. ACK WHEN READY is a feature of LIC Train Control which has not yet been installed, so it is not possible to meet this condition. Therefore, a dispatcher train sheet cannot be given ACTIVE status under the present LIC implementation. It was decided to leave resolution of this problem until after the conclusion of Full Tracking when the LIC Train Control is implemented.

4.3 Colour Graphics Displays

This section describes the performance of the colour graphics train location display at the conclusion of the Full Tracking tests. The three colour CRT's correctly show all status information described in Section 2.3.2. The main track, sidings, and designated additional trackage between North Vancouver and Lillooet are shown in white. Switching zones, e.g., trackage within the North Vancouver yard limits, are shown in cyan (a shade of blue). All control point and station locations are correctly displayed, to a resolution of 1/4 mile. Figure 4-7 illustrates the CRT Track Layout Diagram.

A LIC-equipped train is shown as a cyan arrowhead pointing in the last inferred direction of travel. The train identifier is displayed above the line of the track if the train is moving southward and below the track if it is moving northward. In the event of loss of communications with a train which is still in the LIC System, the arrowhead disappears, and the train identifier is displayed blinking.

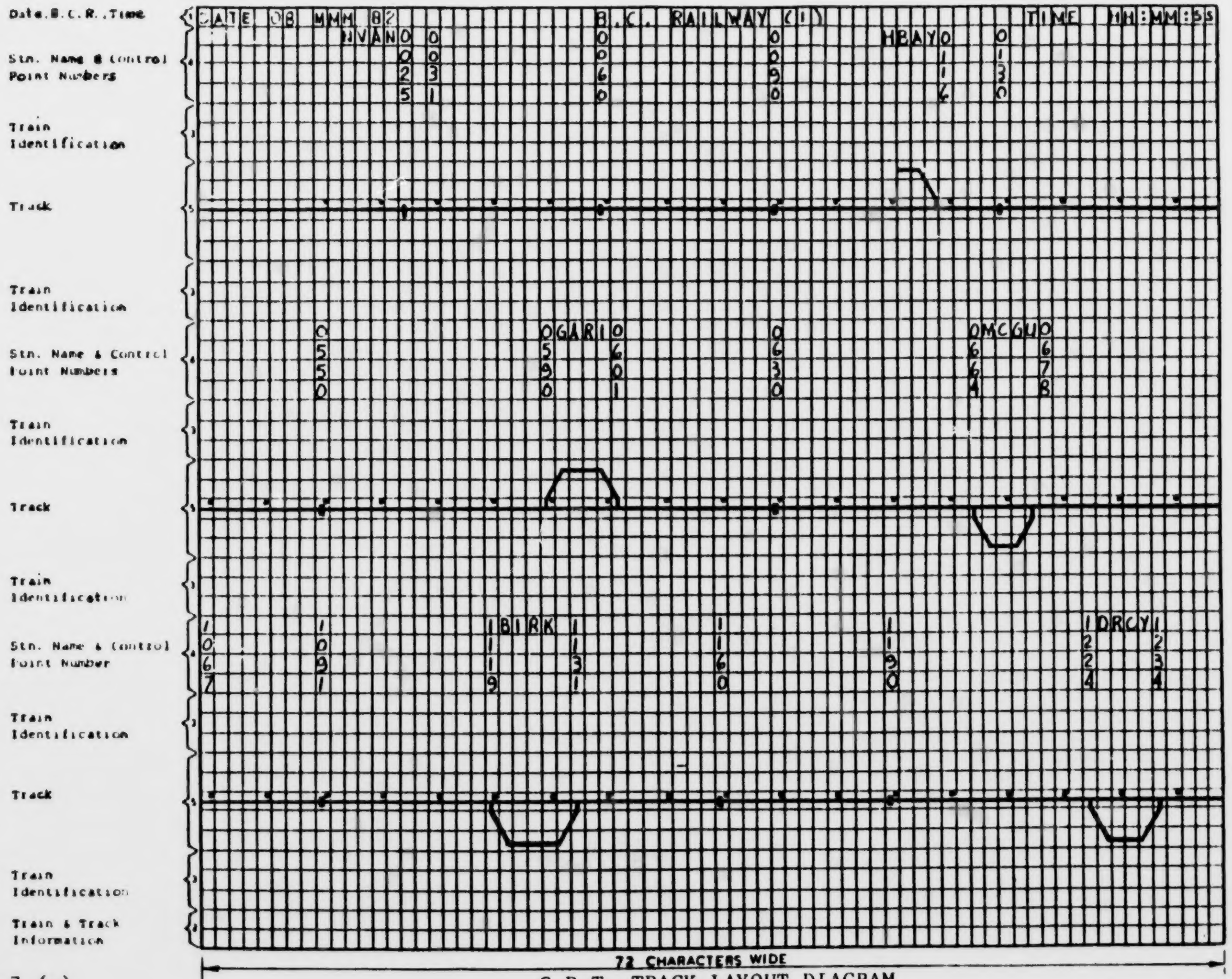

Date.B.C.R..Time
Stn. Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Number
Train Identification
Track
Train Identification
Train & Track Information
DATE 08 MMM 82
B.C. RAILWAY (1)
TIME HH:MM:SS
NVAN
HBAY
GARI
MCGU
BIRK
DRCY
72 CHARACTERS WIDE

FIGURE 4-7 (a)

C.R.T. TRACK LAYOUT DIAGRAM

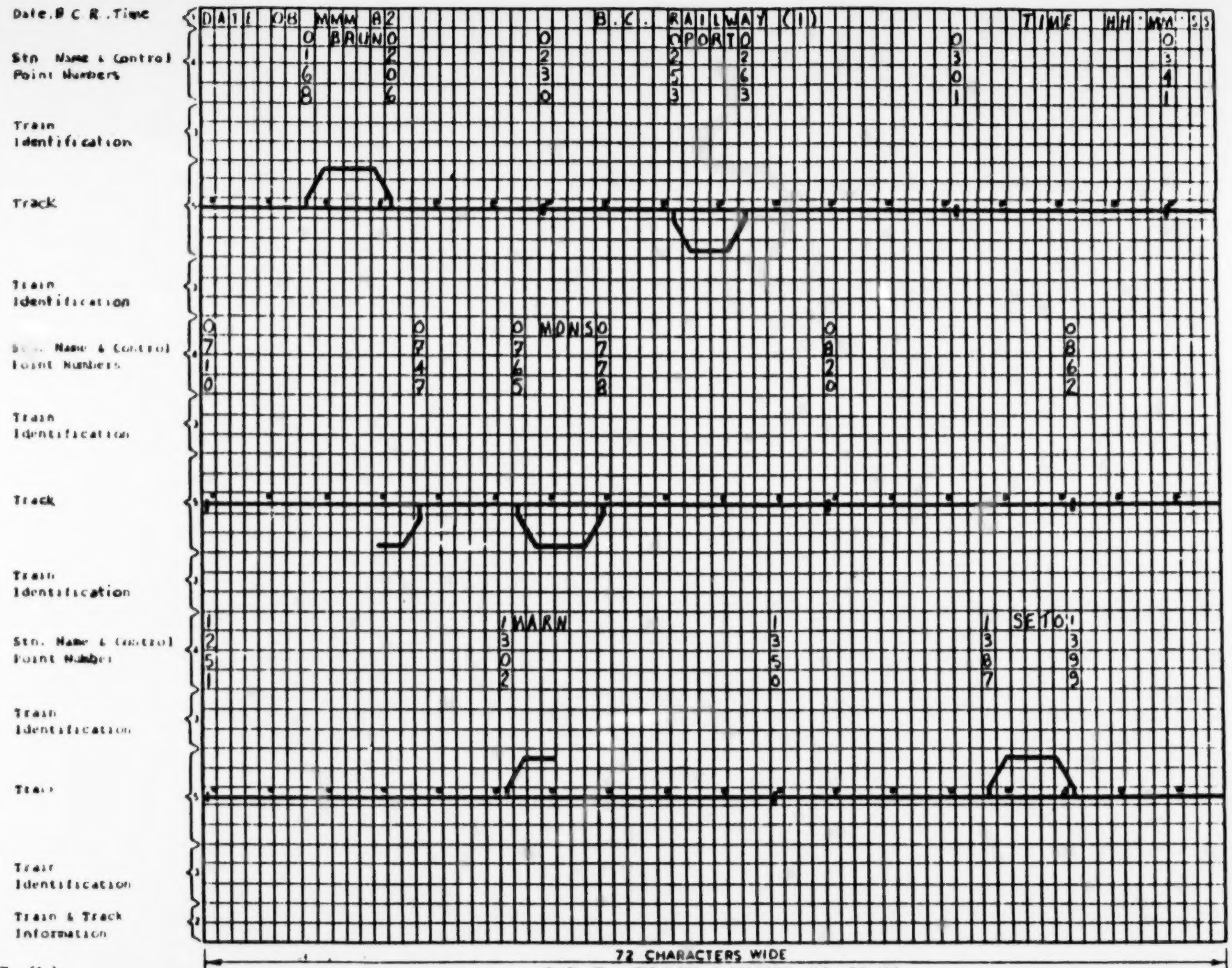

Date, B C R. Time
Stn Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Number
Train Identification
Track
Train Identification
Train & Track Information
DATE 08 MMM 82
B.C. RAILWAY (1)
TIME HH MM SS
BRUNO
OPORTO
MONSO
WARN
SETO
72 CHARACTERS WIDE

FIGURE 4-7 (b)

C.R.T. TRACK LAYOUT DIAGRAM

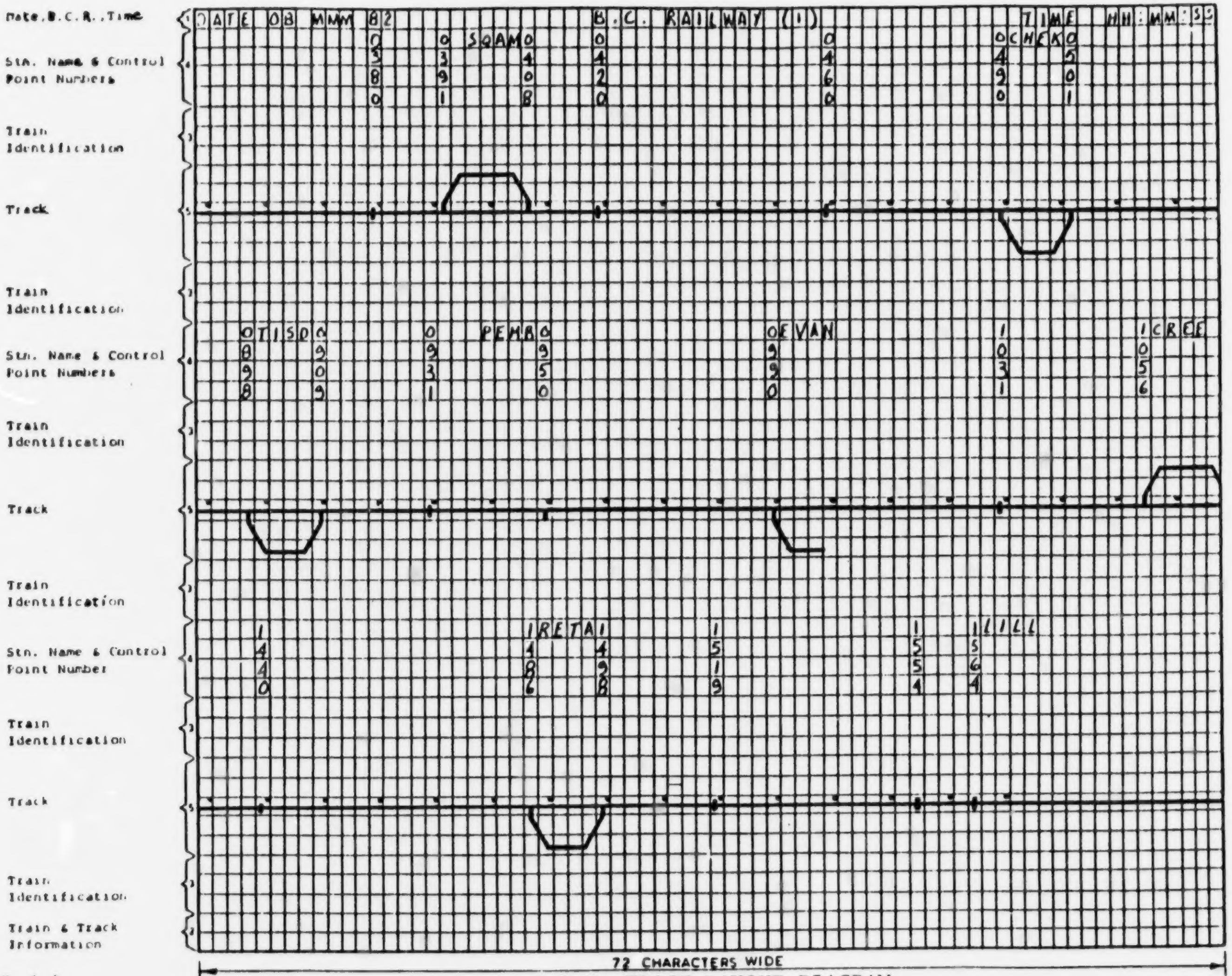

Date, B.C.R., Time
Stn. Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Numbers
Train Identification
Track
Train Identification
Stn. Name & Control Point Number
Train Identification
Track
Train Identification
Train & Track Information
DATE DB MMM 82
B.C. RAILWAY (1)
TIME HH:MM:SS
SQAM
CHEK
OTISD
PEMB
EVAN
CREE
RETA
LILL
0380
0391
0408
0420
0460
0490
0501
0898
0909
0931
0950
0990
1031
1056
1440
1486
1498
1519
1554
1564
72 CHARACTERS WIDE

FIGURE 4-7 (c) C.R.T. TRACK LAYOUT DIAGRAM

4.3.1 Problems

Initially the orientation of the arrowhead corresponded to a train's original direction of travel only and did not change if the train reversed direction.

A further problem arose in that upon loss of communications with a northward train the train identifier reverted to the upper side of the track (the normal position for a southward train). It was essential to correct this problem so that the system would always show the most recently inferred train direction if communications failure occurred. The error was found to have resulted from a misinterpretation of the original specifications, and the problem was corrected.

On several occasions a discrepancy was noted between the known actual location of a train and the position shown on the colour graphics display. On December 15 and 16, 1982, the V-10 track vehicle was operated from North Vancouver to Lillooet and return in order to carry out a detailed train location test. The central office computer records were closely monitored during the test, and similar location display problems were observed.

Section 3.4.1 referred to an occasional lapse of up to several minutes between the reception of an ELU report by the DCP and its arrival at the HOST computer. As the HOST is responsible for control of the colour graphics display it is evident that such delays could lead to erratic behaviour of the train location symbol. The resolution of this problem is described in Section 3.4.1.3.

4.3.2 Evaluation

After the problems described above were corrected, the colour graphics train location display was found to meet specification subject to the limitations described in the following paragraph.

Train location on the graphics display is based primarily on reported odometer readings. The route taken by a train at a control point is inferred from the transponder crossing record, but the odometer must indicate that a unit has passed the actual transponder location in order that the display be correct. Because of the 1/4-mile resolution of the colour graphics, a small odometer error can result in the appearance of the arrowhead train symbol in a display position adjacent to the correct location. This matter is not serious on the main track between sidings, but if the train is at a control point the error can mean the difference between showing it at the switch on the main track and in the clear in the siding. For this reason it may be found necessary to make greater use of transponder crossing records as well as the odometer data to generate the train location display.

4.4 Dispatcher Displays And Reports

The HOST System Software Specification indicates that the system will provide dispatcher displays and reports in the following three categories:

1. TRAIN SHEET REPORTS, which contain data pertaining to a single train and are available on demand either as CRT displays or in hardcopy.
2. LOGS, which contain information relating to system activity over a defined period. The system normally prints logs covering the preceding 24 hours at midnight each day. These reports are also available on demand, but only in printed form.
3. SYSTEM DISPLAYS AND REPORTS, which are summaries of information pertaining to all trains in the system and are available on demand.

This section describes the dispatcher displays and reports presently implemented.

4.4.1 Train Sheet Reports

Five train sheet reports are available under the menu heading "Displays & Reports":

1. TRAIN STATUS REPORT - contains LIC operating information such as: train ID, lead unit and caboose, current tracking data, and outstanding alerts.

2. SUPPLY DATA SUMMARY - contains all information entered as supply data, the arrival data if relevant, and the initials of each dispatcher concerned with the train together with the duration of his or her responsibility.

3. CREW DATA SUMMARY - contains all data (name, call time, departure, arrival, and off-duty times) for all crews handling the train. Data may be entered via the Crew Data or Arrival Data functions of the Train Sheet Data Entry menu.

4. TRAIN PERFORMANCE - contains a record of all control point crossings and may also have dispatcher's notes associated with any crossing. The average speed between control points is calculated automatically and listed along with the direction of travel at each crossing. Will also provide delay report after arrival of train. With the implementation of LIC Train Control, this report will also record all written authorities issued to the train.

5. EXCEPTION REPORT - contains a list of the exceptions or abnormal conditions recorded for the train. Exceptions include such events as speak-ups, communications failure, and speedometer failure.

The last four reports together form the full train sheet which is printed automatically when the chief dispatcher completes a train subsequent to its arrival.

4.4.2 Logs

Two printed reports are available on demand under Displays & Reports menu heading "Logs & Reports". The Train Sheet Summary and dispatcher Duty Log are also printed automatically at midnight each day.

1. TRAIN SHEET SUMMARY - lists the control point crossing times of every train during a defined period (e.g., since the previous midnight). The list is divided into two sections according to the direction and is followed by a record of the written authorities issued during the report period.

2. DUTY LOG - contains information pertaining to every dispatcher who has been on duty during the report period. This information includes: dispatcher identification, log on/off times, the number of trains active during the shift, and a record of the dispatcher's keyboard activity. The Duty Log is available on demand only to the chief dispatcher.

4.4.3 System Displays and Reports

Two items are available under this heading as displays or printed reports: Train Sheet Status and Summary Lineup.

1. TRAIN SHEET STATUS - lists each train by its identifier under one of the following status headings:

   (a) Active

   (b) Proposed

   (c) Called

   (d) Deactivated

   (e) Complete

   (f) Annulled

2. SUMMARY LINEUP - lists all trains in the system with the following data for each:

   (a) Train Identification

   (b) Lead Engine Identification

   (c) Tracking status of train (Proposed, Active, etc.)

(d) Originating control point or station.

(e) Destination control point or station.

(f) Last control point crossed (later to include an indication of the type of authority held).

(g) Time lead engine crossed last control point.

(h) Operating status of train at last control point crossing.

(i) Duration of service since called time or since train became provisional.

(j) Name of Engineman

(k) Name of Conductor

The screen is continuously updated to reflect current conditions.

TRACK LINEUP is hardcopy form of Summary Lineup, and is the only form of lineup that can be given out to track personnel. The format of the printed version reflects current B.C. Railway practice.

4.5 Shift Change Procedure

As the LTC System is not yet in active use for train dispatching, the Dispatcher Shift Change feature is used only to gain access to the system for test purposes. Log On and Log Off are the only shift change menu items presently implemented.

To log on at the start of a shift, the dispatcher selects the Shift Change menu, positions the cursor at Item 4, LOG ON DUTY, and presses RETURN. He must then enter his name and password to complete the log on process.

To log off, the outgoing dispatcher selects the Shift Change menu, positions the cursor at Item 3, LOG OFF DUTY, and presses RETURN. This completes the abbreviated log on/log off procedure currently in effect.

4.6 Overall Evaluation

The LIC dispatcher interface which was implemented and tested in conjunction with Full Tracking comprised two principal functions: automatic train sheet manipulation and a colour graphics train location display.

With the exception noted in Section 4.2.4, all features of LIC train sheet manipulation were tested successfully. The system produced a train sheet which was found suitable both for the purposes of train dispatching and as a management record. The displays and reports produced in conjunction with the LIC train sheet were also considered suitable for the purposes of the Railway.

The colour graphics tracking display appeared to meet most of its basic specifications; however, the accuracy of its representation of train location was occasionally somewhat erratic (Section 4.3). While neither of the apparent causes of the problem is directly related to the graphics display per se, a full evaluation of its performance must be deferred to a later report.

5.0 RELIABILITY AND PERFORMANCE

The LIC prototype system final report (TDC Document TP1993 previously referred to) included an analysis of all failures which interfered with system performance. The reliability prediction technique thus established was based on component failure rates derived from actual field test data. Failure rates should be considered for each of the following subsystems:

1. HOST subsystem (considered separately).

2. DCP subsystem (considered separately).

3. Communications subsystem.

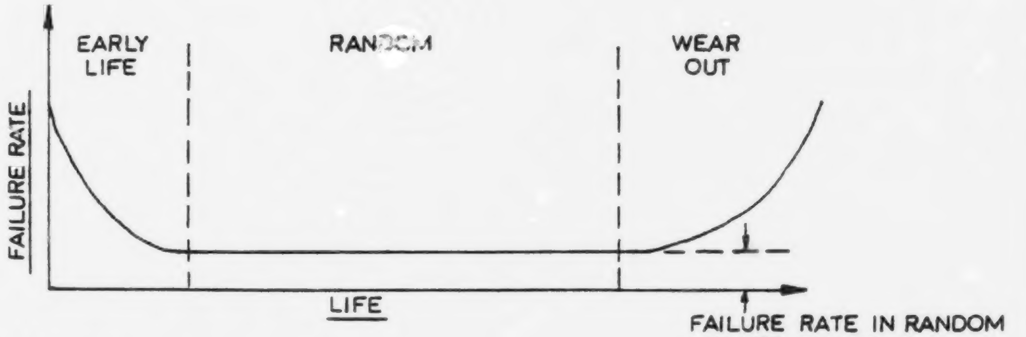
4. Train subsystem.

These component failure rates contribute in an additive or series manner to the overall system failure rate. Given this overall rate the reliability figure R for the system may be calculated from the following expression:

$R = \exp (\lambda t)$ where λ = total system failure rate
t = mission time.

The failure rates for the components given can be determined by identification of failures logged in the problem reports during the test period.

A proper discussion of system reliability must take into account the general nature of the distribution of failure rates with time. This distribution takes the form of the curve shown in Figure 5-1 (the "bathtub curve").



FAILURE RATE IN RANDOM FAILURE PHASE IS APPROXIMATELY CONSTANT

FIGURE 5-1

Systems operating in the early-life region exhibit a high failure rate which can be attributed to design faults, software problems, premature component failures, and installation problems.

An examination of the problem reports during the test period suggests that the LIC System was operating in the early-life region for the duration of testing. This decision was based on the following facts drawn from the reports:

1. The start of the test period coincided with the initial point on the bathtub curve, i.e., there was no burn-in period.

2. Many instances of installation-related problems were logged as failures during the test period, e.g., locomotive interrogator mounting problems.

3. Hardware design faults were found which required circuit modifications, some of which were not fully implemented by the completion of testing, e.g., locomotive axle generator modifications.

4. Software bugs and design faults were discovered and progressively corrected during the test period. The solutions to several such problems have not yet been implemented.

It is considered that any reliability figures calculated during the test period will carry little engineering significance and will not represent the true potential for LIC reliability. The period of random failure, where overall failure rate is reasonably constant, is considered the most significant for reliability predictions. It has been decided therefore that the reliability of the LIC System cannot be accurately quantified at this time.

The Railway intends to continue to monitor failures exhibited by the system in order to determine the transition from the early-life to random failure rate region. Reliability data will be gathered following this transition. A full analysis will be included with the follow-up report to TDC at the conclusion of contract Task 9 (stand alone operation).

It should be noted that it is intended to report only reliability data with a sound engineering basis. At this critical phase of LIC implementation, to report reliability figures based on early-life failures may irrevocably prejudice the views of potential users.

6.0 CONCLUSIONS AND RECOMMENDATIONS

LIC Train Tracking and Dispatcher Assist functions have been fully evaluated under operational conditions, according to criteria set forth in Tasks 1-4 of the contract. From the results obtained, it may be concluded that:

1. The mean rate of transponder detection and reporting, averaged over all units tested, meets tracking requirements.
2. Communications coverage, measured as the ratio of valid ELU responses to DCP transmissions and averaged over all units, meets tracking requirements. The presence of certain geographic areas of reduced coverage is still a problem. Improvement in these areas is necessary before implementation of LIC Train Control.
3. Train Location on the colour graphics display meets tracking requirements but requires modification for use in Train Control.
4. The LIC Dispatcher Interface was found acceptable by the B.C. Railway Chief Dispatcher.
5. The accuracy of the locomotive odometer did not meet the prescribed criterion with sufficient consistency to be acceptable for Train Tracking. Work to improve odometer performance will be carried on parallel with the implementation of Train Control. However, it is expected that the odometer will be acceptable with the previously defined modifications (Section 3.4.2.3).

On the basis of the above conclusions, B.C. Railway recommends that the LIC project proceed with incorporation and evaluation of Train Control as described in the System Functional Specification. Furthermore, the Railway makes the following specific recommendations:

1. The Railway should continue to test odometer calibration with particular regard to the procedure for full calibration. In addition, the Railway should make known to potential suppliers the specific requirements for axle generators which have been determined in this study.

2. The Railway should continue to gather information concerning train location on the colour graphics display. With the introduction of Train Control, it may prove necessary to display trains by both odometer and transponder crossing record. This change is required to ensure positive train location at control points.

3. The Railway should continue to test the dispatcher interface to confirm the proper association and disassociation of units with train sheets, as the results were inconclusive during the tracking tests (Section 4.2.4). When Train Control has been implemented, it will be possible to carry out more extensive tests of the dispatcher interface.

REFERENCE MATERIAL

List of References

1. Functional Specifications of the Location, Identification and Control System (Volume I and II) Datap Systems. April 1980

2. HOST System Specification, Datap Systems - Document 6015-101-12. April 27, 1981

3. Definition and Application of a Base-Line LIC System Using a Data Collection Processor, Glenayre Electronics - Document GL-2025-001. April 1980

4. DCP/HOST Communications Protocol, Glenayre Electronics - Document GL-3738-001. December 15, 1981

5. Train Location, Identification and Control Prototype System, Document TP1993 - Prepared for Transport Canada. February 1, 1979

6. DCP/ELU Communications Protocol and Message Catalogue, Glenayre Electronics - Document GL-2025-005. October 13, 1979

7. Location, Identification and Control System DCP Software Specification, Glenayre Electronics - Document GL-3488-001. December 7, 1981

Glossary

BAUD

Unit of signalling speed; baud rate is the number of discrete signal conditions occurring per second.

BLOCK

A uniquely defined and identified length of track in LIC territory; may be one of the following types: main track; siding; additional trackage; or switching zone.

CAB DISPLAY UNIT

An alphanumeric display in the locomotive cab which indicates train speed, location (mileage), and other information (Section 2.1.2).

CABOOSE LOGIC UNIT

The version of the ELU which is used in a caboose; CLU capability is limited to transponder reporting (Section 2.1.2).

CHAINING

Measurement by survey of the exact location of points on the right-of-way.

CONTINUOUS SERVICE

Situation in which one or more members of a train crew remains on duty beyond the regular crew-change point.

CONTROL POINT

A uniquely identified location which defines a boundary of a block of track in LIC territory (Section 2.2.1).

CURSOR

The indicator on a video display terminal screen of the position at which the next character typed will appear - often appears as a blinking underline character. Cursor control keys (or ARROW keys on the VT-100 terminal) allow the user to change the position of the cursor without entering data.

DIGITRAC

That part of the LIC train equipment (other than the engine odometer) which is used to establish train location; comprised of transponders, interrogator coil unit, and ICU controller in the engine logic unit (Section 2.1.2, Appendix "C").

FRINGE ZONE

An area of LIC radio coverage which is within range of more than one remote site radio (Section 2.2.3).

FULL CALIBRATION

Automatic calibration of the locomotive odometer which includes the measurement and application of a factor to correct for actual wheel diameter (Section 2.2.2).

LINEUP

A list of the last reported location and direction of all trains currently operating or to be operated during the period for which the lineup is valid; used primarily as an advisory for track and other maintenance personnel (Section 4.4.3).

MENU

A means of human-computer interaction in which the user is presented with a display listing a number of choices from which the desired activity can be selected; the choice is indicated by entering a number, positioning the cursor, or similar means.

MODEM

Short for modulator-demodulator - a device which converts a serial bit stream into a form which can be transmitted by radio or telephone.

NORMAL ZONE

The area which is within LIC radio range of one and only one remote communications site (Section 2.2.3).

PARITY

A parity bit is a single bit (1 or 0) appended to a word or other unit of digital data in order to make the total number of 1 bits in every such unit either even or odd; the choice of even or odd parity is part of the definition of the communications protocol in effect. Parity checking permits detection of errors in single bits or odd numbers of bits in a message.

PROVISIONAL TRAIN

Every train which enters the LIC System will speak up at the first transponder it encounters; any unit which does so and which is not already associated with a dispatcher-created train sheet will be designated a provisional train.

REMOTE SITE UNIT

A component of the LIC communications subsystem at each remote microwave/radio repeater site; interface between the microwave channel and the UHF train radio (Section 2.1.3).

SIMPLE CALIBRATION

Automatic calibration of the locomotive odometer in which the DCP informs the engine logic unit of the number and exact location of a suitable upcoming transponder; upon detecting the transponder the ELU sets its odometer to the mileage given (Section 2.2.2).

SPEAK-UP

Procedure by which an LIC-equipped train makes its existence known to the central computer (Section 2.2.1).

SUPPLY

A record of the engines, caboose, crew and similar data which define the physical make-up of a train; this information is transmitted to the dispatcher prior to the train's departure and is recorded as part of the train sheet (Section 4.2).

TRACKING

The process by which the LIC central computer maintains a record of the identity and current location of equipped units within its territory.

TRACK MODEL

One or more computer data files which define the trackage in LIC territory in terms of control point location, grades, track speeds, and other factors (Appendix "B").

TRAIN

A collection of one or more units associated with a single LIC train sheet.

TRAIN GRAPH

a time-vs-distance graph produced by the DCP on a dedicated printer to show the approximate location of LIC-equipped units at any time (Section 2.2.4).

TRAIN SHEET

Under LIC operation, a train sheet is the computer's record of all information related to a single train (Section 2.3).

TRANSPONDER

A passive electronic device fastened to the roadbed in a location precisely known to the LIC central computer; when energized by a passing LIC vehicle, it transmits a unique identifier (Section 2.2.1).

UNIT

A uniquely identified rail vehicle of one of the following types: engine, RDC (Budd Car), caboose, or other.

WHEEL WEAR FACTOR

A factor applied by the ELU to locomotive odometer readings to correct for the difference between nominal and actual engine wheel size.

WRITTEN AUTHORITY

Part of LIC Train Control (not yet implemented) which is used to convey authority to a train or Maintenance-of-Way crew to move on or occupy a specific portion of track (Section 2.1).

Abbreviations

BCH

Bose-Chaudhuri-Hocquengham (code) - A sequence of bits appended to a digital message prior to transmission to be used by the receiver to detect transmission errors (a generalization of the Hamming codes).

C/S

Continuous Service

CCS

Central Computer Subsystem - Section 2.1.1

CDU

Cab Display Unit - Section 2.1

CLU

Caboose Logic Unit - Section 2.1.2

CMS

Communications Subsystem - Section 2.1.3

CRT

Cathode Ray Tube - A name applied to the screen of a video display or monitor.

DCP

Data Collection Processor - Section 2.1.1

DPSK

Differential Phase-Shift Keying - A means of serial data transmission in which the phase of the transmitted signal is changed according to the logic levels (1 or 0) of the current and previous bits.

ELU

Engine Logic Unit - Section 2.1.2

FSK

Frequency Shift Keying - Mode of serial data transmission in which a change of logic level is represented by a change in signal frequency.

HOST

(Not really an abbreviation, the main (mini-computer) component of CCS.) - Section 2.1.1

ICU

Interrogator Coil Unit - Section 2.1.2

LIC

Location, Identification and Control

OS

Train Report - Traditional railroad term for a report to the dispatcher of the arrival, departure, or passage of a train.

RDC

Rail Diesel Car - Self-propelled passenger rail vehicle; also known as a Budd Car.

RS-232-C

An electrical standard for the interconnection of digital equipment using serial data transmission.

RSU

Remote Site Unit - Section 2.1.3

TDC

Transport Canada, Research and Development Centre - Ottawa

UHF

Ultra-High Frequency - Radio frequencies between 300 MHz (Megahertz, or million cycles per second) and 3000 MHz; the LIC train radios operate in the 450 MHz band.

APPENDIX A

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

CENTRAL COMPUTER SUBSYSTEM

BRITISH COLUMBIA RAILWAY

CENTRAL COMPUTER SUBSYSTEM

1.0 Introduction

The Central Computer Subsystem contains all hardware and software necessary to monitor, co-ordinate and control all activities within the LIC System. It is constructed around two sets of redundant processors; specifically the DCP's (Data Collection Processors) which act as a stand-alone system to provide simple tracking functions and act as a front-end processor for the two HOST computers. Referring to the layout indicated on Drawing C 5214 in Appendix A, other devices have been arranged around the computers to provide data storage, display and input functions. This Section will describe each hardware device in terms of its model, manufacturer and functions. Section 5 of this document is the HOST computer software requirements which provide the operational requirements of each device.

1.1 HOST Computers

1.1.1 PDP-11/44 Computer

The two identical HOST computers are Digital Equipment Corporation's PDP-11/44 with 512K bytes of ECC MOS memory with battery backup for the memory. A real time clock with programmable frequency, provides the interrupts to the CPU. A watchdog timer is also provided to detect CPU failure and provide the failure indication to the fault detector indicators.

Some of the features of the PDP-11/44 are:

1. 400 powerful, hardwired instructions.
2. Power Fail and Automatic Restart.
3. Hardware implemented multiply and divide instructions.
4. Integral memory management hardware that provides program protection, memory relocation and addressing.

5. Integral extended instruction set (EIS) that provides hardware fixed-point arithmetic in double-precision mode (32-bit operands).

6. Self-test diagnostic routines which are automatically executed every time the processor is powered up.

7. Automatic bootstrap loader which allows system restart from a variety of peripheral devices.

8. 8KB of Cache memory.

9. Expandable to 1 MB of memory.

10. All system elements, processor, memory and peripherals, plug into a single asynchronous high-speed bus, which transfers all addresses and data. Known as the UNIBUS, this bi-directional bus enables easy interfacing and simplifies the construction of multi-processor or shared peripheral configurations.

11. The interrupt system for the PDP-11 is fully-vectored, eliminating high-overhead software that determines the device service routine and code necessary to save system status.

1.1.2 Disc. Controller

The RL02 Disc. subsystem is a multi-channel disc. drive controller, which can support up to a maximum of 4 moving head disc. drives which use a removable, top loading cartridge. It has a peak transfer rate in excess of 512 kilo bytes per second.

In the present configuration, each computer will have two 10 MB disc. drives, with a total storage capacity of 20M bytes (each computer).

1.1.3 DZ-11 Multiplexor

The DZ-11 Multiplexor connects the PDP-11 UNIBUS with 16 asynchronous serial communication lines. The character formats and operating speeds are programmable for each line.

Some of the important features of DZ-11 are:

1. Each line of the DZ-11 may run at program-selectable speeds up to 9600 bits per second.
2. Complete program control of each line for:
   - (a) Data Rate: 15 Standard Speeds
   - (b) Character Size: 5, 6, 7 or 8 Bits
   - (c) Stop Code Length: 1, 1.5 (5-Bit Data Only) or 2 Bits
   - (d) Transmission Mode: Full Duplex
   - (e) Parity Generation and Checking
3. 64-Character hardware buffer for received characters.
4. Data set control for full duplex dial-up operation with Bell 103 or 113 modems or equivalent.
5. Hardware break detection and program-controlled break generation.
6. EIA RS232-C/CCITT V.24.
7. Incoming characters are silo buffered. Outgoing characters are processed on a program interrupt basis.

1.1.4 Parallel Digital I/O

The DR11-C Device Register Interface is an integral logic module which forms a self-contained interface between the PDP-11 UNIBUS and a user's peripheral. The DR11-C performs all of the necessary tasks to communicate with the PDP-11, so that the user may easily interface his device.

The DR11-C permits bi-directional transfer of 16 bits of information between a user's device and PDP-11 UNIBUS. The three functional sections of the DR11-C are: 16-bit 1/0 Buffer, Bus and Interrupt Control Unit, and the Address Selector Unit.

Information from the UNIBUS is stored in a 16-bit buffer register. Once this register has been set under program control, the outputs are available to the device until the register is loaded with new data from the UNIBUS. The register can also be read onto the UNIBUS.

The DR11-C also provides 16 lines of input to UNIBUS transmitters. This allows data from user devices to be read onto the UNIBUS.

1.1.5 Cartridge Tape Drive

The TU58 will be used for historical data backup and maintenance functions. The TU58 or DECTAPE II is a random-type access, mass memory tape subsystem capable of 256K bytes per drive. The DECTAPE II is block-addressable and pre-formatted at 800 bits per inch. It is divided into two tracks each of which is broken up into 2048 blocks of 128 bytes each. It is a fixed address system and access from the HOST computer is on numbered blocks only.

1.2 HOST's Peripherals

1.2.1 Programmer's Terminal

The Programmer's Terminal is interfaced through a DL-11E to the CPU. The terminal is an LA120 printer with keyboard, as described in the following section. It is used for bootup, severe software error messages and other functions as may be assigned to it.

1.2.2 Aydin Control 5217R Display Generator

Three Aydin 5217R Display Generators are provided, each interfaced to the HOST computers via the DZ-11 serial multiplexor as described in Section 4.1.3. The display generators are switched between the on-line HOST and the standby HOST via the Fault Detector. The on-line HOST controls the Display Generator until such time as the standby HOST must take over. The 5217R Display Generators are rack mountable and are provided without keyboards. A keyboard version, 5217, is provided for offline display design, and for a spare.

Some of the features of the Aydin 5217R display generator are mentioned below:

1. Eight colours red, green, cyan, yellow, blue, orange, magenta and white.
2. Selective two level intensity by character.
3. Reverse background.
4. 256 Alphanumerics and special symbols.
5. Special symbol fonts custom designed to the LIC application.
6. 80 characters per line.
7. 48 lines per page.
8. 3840 characters per page.
9. Selective blink by character.
10. Selective colour by character.
11. Selectable character size (2).
12. Flicker free display - no interlace jitter.
13. Video output for standard RGB colour and monochrome monitors.
14. Selectable 4 line rotable menu area.
15. Full edit capability (with keyboard).
16. Operator oriented cursor (with keyboard).
17. Variable page formatting.

1.2.3 VT100 - Video Terminal

The VT100's are interfaced to the CPU via the DZ-11 multiplexor and can operate under 15 different baud rates, with other selectable options as per the DZ-11 details in 4.1.3.

Each computer has its own interface to these terminals, which is switched by the fault detector upon on-line's failure.

Some of the features of VT100 are listed below. It should be noted that all VT100's will be equipped with the advanced video options.

1. Detachable keyboard.
2. Standard numeric/function keypad.
3. Selectable double-size characters.
4. Up to 132 characters per line.
5. Bi-directional smooth scrolling.
6. Split screen capability.
7. Normal or reverse video on a character-by-character basis.
8. Optional blinking, underline, and dual intensity characters.
9. Black characters on white screen or vice versa, user-selectable.
10. Fixed and settable tabs.
11. US and UK character sets.
12. Line drawing graphic characters.
13. Built-in self-test diagnostics on power up.
14. Composite video output for auxiliary monitors.
15. Composite video input for video overlay.
16. Transmission speeds up to 19,200 baud.
17. VT52 compatibility mode for easy upgrade.

18. Seven light-emitting diodes for operator information/diagnostic aids.

19. Non-volatile Random Access Memory holds feature settings.

20. Full-duplex, asynchronous communication lines.

The SETUP key replaces the display screen by a status screen. The status screen allows the user to select character displays, transmission rates, and column settings, and then return to the display screen without interferring with information entered previously. Tab stops, both fixed and settable, are standard within the full 80 or 132 column range. Keyboard and/or computer-settable tab stops facilitate formatting columnar data.

Composite video output allows the VT100 to drive an auxiliary monitor, thus supporting applications that involve displaying test or data to a group of people. Composite video input allows the user to overlay video output from a remote terminal.

1.2.4 LA120 Printing Terminal

Similar to the VT100 configuration, the LA120's are also interfaced via the DZ-11. Each computer has its own interface which is switched to the peripheral, depending upon who is currently on-line. It should be noted that even though the LA120 has a keyboard, it may be disabled from input.

The LA120 DECwriter III, a 180 cps hardcopy terminal, boosts throughput by combining bi-directional smart printing and a 1K character buffer with fast horizontal and vertical skipping over white space. The LA120 also offers over 45 keyboard-selectable features, which include:

1. 180 characters per second.

2. Up to 9600 baud (14 baud rates plus 8 split baud rates).

3. 7 x 7 dot matrix.

4. 1K character buffer.

5. Smart printing (seeks shortest path to next print position).

6. Bi-directional printing.

7. High speed horizontal and vertical skipping over white space.

8. 8 font sizes, including compressed and expanded fonts.

9. 6 line spacings.

10. Selectable form lengths up to 14 inches.

11. Built-in circuit self-test on power up.

12. Printing self-test.

1.2.5 Special Functions Console

The Special Functions Console is incorporated as a HOST software function, using the VT100 dispatcher console.

1.2.6 Colour Monitors

The three colour monitors shown in Appendix A for the central subsystem hardware are Aydin 8025, 19 inch high resolution monitors. A fourth monitor will be available for backup in case of failure.

1.3 DCP (Data Collection Processors)

The Data Collection Processors will be a micro computer based device incorporating the necessary microproccessor, read-only memory, read/write memory and required digital and serial input/outputs to provide interface between the Communications Subsystem and the HOST computers. It is being manufactured by Glenayre Electronics to suit the specific needs of the LIC System and to satisfy many general purpose requirements in the area of vehicle tracking. A description of the application of the DCP to the LIC System is contained in Glenayre's GL-2025-001 (Issue 4).

"Definition and Application of a Baseline LIC System Using a Data Collection Processor."

1.4 Fault Detector and Standard Time Clock

1.4.1 Fault Detector

The Fault Detector will be a custom manufactured device used to initiate a transfer of control between the on-line and standby HOST/DCP pairs. The Fault Detector will control the interface switches on each of the human interface devices and the channel switches (separate unit) on the communications data channels. Control is initiated by:

1. Watchdog timer time-out on either of the two on-line computers.
2. Commanded switchover on detection of a serious fault by either computer.
3. By manual initiation.

The Fault Detector includes a series of display indicators to provide indication of major device status such as:

1. Designation of which computer pair is on-line or standby.
2. Disk failure.
3. DCP/HOST communications failure.
4. DCP/DCP and HOST/HOST communications failure.
5. Other errors as identified.

1.4.2 Standard Time Clock

The Standard Time Clock is provided as a standard crystal controlled time of day clock which outputs time and date (accurate to the nearest second) on a single RS-232-C serial port. Each computer in the system continuously monitors the periodic (once per minute) transmission from the clock and uses that transmission as a check on the time of its own internally kept real-time clock. This technique thus ensures that all processors are synchronized to the same time signal and that they are operating on the same time base.

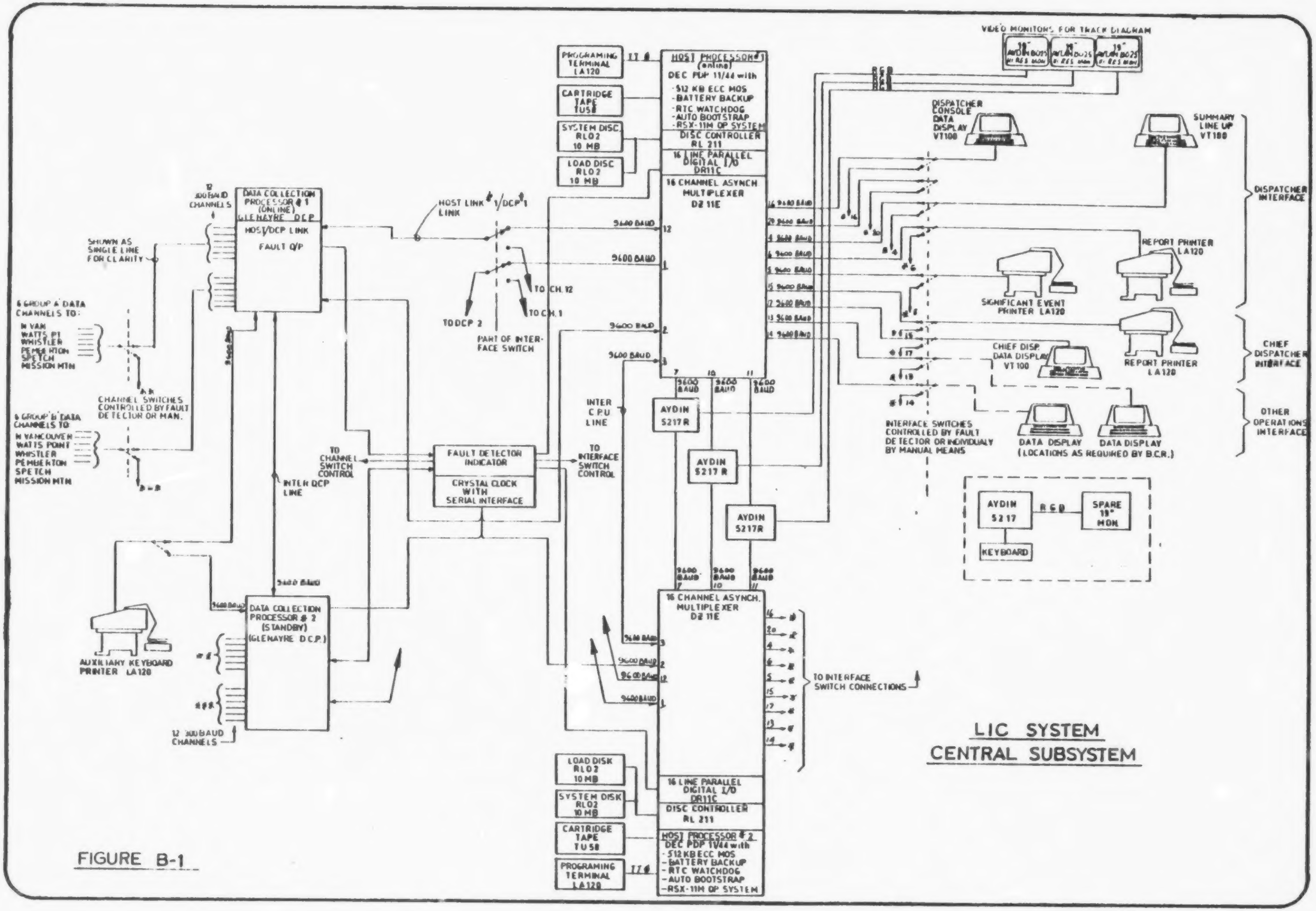
The clock will operate as an output only device - it regularly and periodically outputs its time and does not need to be interrogated by the computer. Facility is provided on the clock for visual display of current time and to reset the time.

The serial line clock is an SLC-1, manufactured by Digital Pathways.

APPENDIX B

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

HOST AND DATA COLLECTION PROCESSOR LIC TRACK MODELS


VIDEO MONITORS FOR TRACK DIAGRAM
19" AYDIN 8025 HI RES MON
19" AYDIN 8025 HI RES MON
19" AYDIN 8025 HI RES MON
R G B
PROGRAMING TERMINAL LA120
TT Ø
CARTRIDGE TAPE TU58
SYSTEM DISC RL02 10 MB
LOAD DISC RL02 10 MB
HOST PROCESSOR # 1 (online)
DEC PDP 11/44 with
-512 KB ECC MOS
-BATTERY BACKUP
-RTC WATCHDOG
-AUTO BOOTSTRAP
-RSX-11M OP SYSTEM
DISC CONTROLLER RL 211
16 LINE PARALLEL DIGITAL I/O DR11C
16 CHANNEL ASYNCH MULTIPLEXER DZ 11E
9600 BAUD
12
1
2
3
7
10
11
16
20
4
6
5
15
17
13
14
AYDIN 5217R
AYDIN 5217 R
AYDIN 5217R
DISPATCHER CONSOLE DATA DISPLAY VT100
SUMMARY LINE UP VT100
DISPATCHER INTERFACE
REPORT PRINTER LA120
SIGNIFICANT EVENT PRINTER LA120
CHIEF DISP. DATA DISPLAY VT 100
REPORT PRINTER LA120
CHIEF DISPATCHER INTERFACE
DATA DISPLAY
DATA DISPLAY
(LOCATIONS AS REQUIRED BY B.C.R.)
OTHER OPERATIONS INTERFACE
INTERFACE SWITCHES CONTROLLED BY FAULT DETECTOR OR INDIVIDUALY BY MANUAL MEANS
AYDIN 5217
R G B
SPARE 19" MON
KEYBOARD
12 300 BAUD CHANNELS
DATA COLLECTION PROCESSOR # 1 (ONLINE) GLENAYRE DCP
HOST/DCP LINK
FAULT O/P
SHOWN AS SINGLE LINE FOR CLARITY
6 GROUP 'A' DATA CHANNELS TO:
N VAN
WATTS PT
WHISTLER
PEMBERTON
SPETCH
MISSION MTN
A-B
CHANNEL SWITCHES CONTROLLED BY FAULT DETECTOR OR MAN.
6 GROUP 'B' DATA CHANNELS TO:
N VANCOUVER
WATTS POINT
WHISTLER
PEMBERTON
SPETCH
MISSION MTN
B-B
HOST LINK # 1/DCP # 1 LINK
TO CH. 12
TO CH. 1
TO DCP 2
PART OF INTERFACE SWITCH
INTER CPU LINE
TO CHANNEL SWITCH CONTROL
FAULT DETECTOR INDICATOR
CRYSTAL CLOCK WITH SERIAL INTERFACE
TO INTERFACE SWITCH CONTROL
INTER DCP LINE
AUXILIARY KEYBOARD PRINTER LA120
DATA COLLECTION PROCESSOR # 2 (STANDBY) (GLENAYRE D.C.P.)
12 300 BAUD CHANNELS
16 CHANNEL ASYNCH. MULTIPLEXER DZ 11E
TO INTERFACE SWITCH CONNECTIONS
LOAD DISK RL02 10 MB
SYSTEM DISK RL02 10 MB
CARTRIDGE TAPE TU58
PROGRAMING TERMINAL LA120
TT Ø
16 LINE PARALLEL DIGITAL I/O DR11C
DISC CONTROLLER RL 211
HOST PROCESSOR # 2
DEC PDP 11/44 with
-512 KB ECC MOS
-BATTERY BACKUP
-RTC WATCHDOG
-AUTO BOOTSTRAP
-RSX-11M OP SYSTEM

LIC SYSTEM
CENTRAL SUBSYSTEM

FIGURE B-1

HOST SYSTEM TRACK MODEL

The Track Model used by the LIC System HOST computer is built off-line by a utility task. Railway personnel must enter the required input data into four source files, as follows:

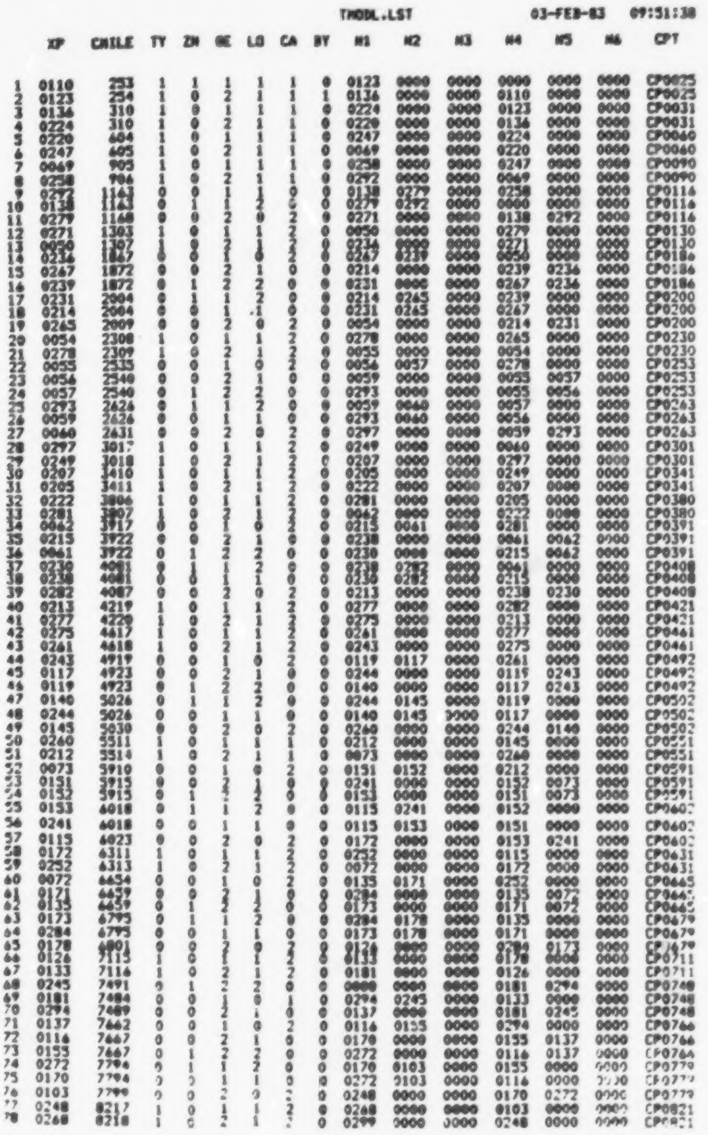
1. Node File: contains location, identification, and other information to define each control point.

2. Transponder File: contains the identification number for each transponder, the control point at which it is located, and its position in feet relative to the control point location; also identifies the transponder(s) immediately adjacent to the north and south.

3. Speed/Grade File: contains the track speed permitted for freight and passenger trains at each control point, together with the grades in the northward and southward directions.

4. Stations File: contains the name of each station on the subdivision, its four-letter abbreviation as used in the colour graphics display, and the control point numbers to the north and south of the station.

The track model builder program uses these files to generate the machine-readable data files which make the computer's track model. The latter files are loaded into the HOST computer at system startup. The track model builder also produces listing files which can be output to a printer. The following pages contain copies of the track model builder input files (XLINK.TXT, NODE.TXT, GRADE.TXT, and STATN.TXT) and the output listing files (BLOCK.LST, NODE.LST, XLINK.LST, and STATN.LST).



```
                                                 TMODL.LST             03-FEB-83   09:51:38

     XP    CHILE  TY  ZN  OE  LO  CA  BY   N1    N2    N3    N4    N5    N6     CPT

 1   0110    253   1   1   1   1   1   0  0123  0000  0000  0000  0000  0000  CP0025
 2   0123    254   1   0   2   1   1   1  0136  0000  0000  0110  0000  0000  CP0025
 3   0136    310   1   0   1   1   1   0  0224  0000  0000  0123  0000  0000  CP0031
 4   0224    310   1   0   2   1   1   0  0220  0000  0000  0136  0000  0000  CP0031
 5   0220    604   1   0   1   1   1   0  0247  0000  0000  0224  0000  0000  CP0060
 6   0247    605   1   0   2   1   1   0  0069  0000  0000  0220  0000  0000  CP0060
 7   0069    905   1   0   1   1   1   0  0258  0000  0000  0247  0000  0000  CP0090
 8   0258    906   1   0   2   1   1   0  0292  0000  0000  0069  0000  0000  CP0090
 9   0292   1143   0   0   1   1   0   0  0138  0279  0000  0258  0000  0000  CP0116
10   0138   1143   0   1   1   2   0   0  0279  0292  0000  0000  0000  0000  CP0116
11   0279   1168   0   0   2   0   2   0  0271  0000  0000  0138  0292  0000  CP0116
12   0271   1303   1   0   1   1   2   0  0050  0000  0000  0279  0000  0000  CP0130
13   0050   1307   1   0   2   1   2   0  0234  0000  0000  0271  0000  0000  CP0130
14   0234   1867   0   0   1   0   2   0  0267  0239  0000  0050  0000  0000  CP0186
15   0267   1872   0   0   2   1   0   0  0214  0000  0000  0239  0236  0000  CP0186
16   0239   1872   0   1   2   2   0   0  0231  0000  0000  0267  0236  0000  CP0186
17   0231   2004   0   1   1   2   0   0  0214  0265  0000  0239  0000  0000  CP0200
18   0214   2004   0   0   1   1   0   0  0231  0265  0000  0267  0000  0000  CP0200
19   0265   2009   0   0   2   0   2   0  0054  0000  0000  0214  0231  0000  CP0200
20   0054   2308   1   0   1   1   2   0  0278  0000  0000  0265  0000  0000  CP0230
21   0278   2309   1   0   2   1   2   0  0055  0000  0000  0054  0000  0000  CP0230
22   0055   2535   0   0   1   0   2   0  0056  0057  0000  0278  0000  0000  CP0253
23   0056   2540   0   0   2   1   0   0  0059  0000  0000  0055  0057  0000  CP0253
24   0057   2540   0   1   2   2   0   0  0293  0000  0000  0055  0056  0000  CP0253
25   0293   2626   0   1   1   2   0   0  0059  0060  0000  0057  0000  0000  CP0263
26   0059   2626   0   0   1   1   0   0  0293  0060  0000  0056  0000  0000  CP0263
27   0060   2631   0   0   2   0   2   0  0297  0000  0000  0059  0293  0000  CP0263
28   0297   3017   1   0   1   1   2   0  0249  0000  0000  0060  0000  0000  CP0301
29   0249   3018   1   0   2   1   2   0  0207  0000  0000  0297  0000  0000  CP0301
30   0207   3410   1   0   1   1   2   0  0205  0000  0000  0249  0000  0000  CP0341
31   0205   3411   1   0   2   1   2   0  0222  0000  0000  0207  0000  0000  CP0341
32   0222   3806   1   0   1   1   2   0  0281  0000  0000  0205  0000  0000  CP0380
33   0281   3807   1   0   2   1   2   0  0062  0000  0000  0222  0000  0000  CP0380
34   0062   3917   0   0   1   0   2   0  0215  0061  0000  0281  0000  0000  CP0391
35   0215   3922   0   0   2   1   0   0  0238  0000  0000  0061  0062  0000  CP0391
36   0061   3922   0   1   2   2   0   0  0230  0000  0000  0215  0062  0000  CP0391
37   0230   4081   0   1   1   2   0   0  0238  0282  0000  0061  0000  0000  CP0408
38   0238   4081   0   0   1   1   0   0  0230  0282  0000  0215  0000  0000  CP0408
39   0282   4087   0   0   2   0   2   0  0213  0000  0000  0238  0230  0000  CP0408
40   0213   4219   1   0   1   1   2   0  0277  0000  0000  0282  0000  0000  CP0421
41   0277   4220   1   0   2   1   2   0  0275  0000  0000  0213  0000  0000  CP0421
42   0275   4617   1   0   1   1   2   0  0261  0000  0000  0277  0000  0000  CP0461
43   0261   4618   1   0   2   1   2   0  0243  0000  0000  0275  0000  0000  CP0461
44   0243   4919   0   0   1   0   2   0  0119  0117  0000  0261  0000  0000  CP0492
45   0117   4923   0   0   2   1   0   0  0244  0000  0000  0119  0243  0000  CP0492
46   0119   4923   0   1   2   2   0   0  0140  0000  0000  0117  0243  0000  CP0492
47   0140   5026   0   1   1   2   0   0  0244  0145  0000  0119  0000  0000  CP0502
48   0244   5026   0   0   1   1   0   0  0140  0145  0000  0117  0000  0000  CP0502
49   0145   5030   0   0   2   0   2   0  0260  0000  0000  0244  0140  0000  CP0502
50   0260   5511   1   0   1   1   1   0  0212  0000  0000  0145  0000  0000  CP0551
51   0212   5514   1   0   2   1   1   0  0073  0000  0000  0260  0000  0000  CP0551
52   0073   5910   0   0   1   0   2   0  0151  0152  0000  0212  0000  0000  CP0591
53   0151   5915   0   0   2   1   0   0  0241  0000  0000  0152  0073  0000  CP0591
54   0152   5915   0   1   2   2   0   0  0153  0000  0000  0151  0073  0000  CP0591
55   0153   6018   0   1   1   2   0   0  0115  0241  0000  0152  0000  0000  CP0602
56   0241   6018   0   0   1   1   0   0  0115  0153  0000  0151  0000  0000  CP0602
57   0115   6023   0   0   2   0   2   0  0172  0000  0000  0153  0241  0000  CP0602
58   0172   6311   1   0   1   1   2   0  0252  0000  0000  0115  0000  0000  CP0631
59   0252   6313   1   0   2   1   2   0  0072  0000  0000  0172  0000  0000  CP0631
60   0072   6654   0   0   1   0   2   0  0135  0171  0000  0252  0000  0000  CP0665
61   0171   6659   0   0   2   1   0   0  0284  0000  0000  0135  0072  0000  CP0665
62   0135   6659   0   1   2   2   0   0  0173  0000  0000  0171  0072  0000  CP0665
63   0173   6795   0   1   1   2   0   0  0284  0178  0000  0135  0000  0000  CP0679
64   0284   6795   0   0   1   1   0   0  0173  0178  0000  0171  0000  0000  CP0679
65   0178   6801   0   0   2   0   2   0  0126  0000  0000  0284  0173  0000  CP0679
66   0126   7115   1   0   1   1   2   0  0133  0000  0000  0178  0000  0000  CP0711
67   0133   7116   1   0   2   1   2   0  0181  0000  0000  0126  0000  0000  CP0711
68   0245   7491   0   1   2   2   0   0  0000  0000  0000  0181  0294  0000  CP0748
69   0181   7484   0   0   1   0   1   0  0294  0245  0000  0133  0000  0000  CP0748
70   0294   7489   0   0   2   1   0   0  0137  0000  0000  0181  0245  0000  CP0748
71   0137   7662   0   0   1   0   2   0  0116  0155  0000  0294  0000  0000  CP0766
72   0116   7667   0   0   2   1   0   0  0170  0000  0000  0155  0137  0000  CP0766
73   0155   7667   0   1   2   2   0   0  0272  0000  0000  0116  0137  0000  CP0766
74   0272   7794   0   1   1   2   0   0  0170  0103  0000  0155  0000  0000  CP0779
75   0170   7794   0   0   1   1   0   0  0272  0103  0000  0116  0000  0000  CP0779
76   0103   7799   0   0   2   0   2   0  0248  0000  0000  0170  0272  0000  CP0779
77   0248   8217   1   0   1   1   2   0  0268  0000  0000  0103  0000  0000  CP0821
78   0268   8218   1   0   2   1   2   0  0299  0000  0000  0248  0000  0000  CP0821
```

HOST TRACK MODEL

FIGURE B-2

```
 79  0299   8632  1  0  1  1  1  0  0232  0000  0000  0268  0000  0000  CP0863
 80  0232   8633  1  0  2  1  1  0  0131  0000  0000  0299  0000  0000  CP0863
 81  0131   8772  0  0  1  0  2  0  0134  0157  0000  0232  0000  0000  CP0877
 82  0134   8777  0  0  2  1  0  0  0165  0000  0000  0157  0131  0000  CP0877
 83  0157   8777  0  1  2  2  0  0  0283  0000  0000  0134  0131  0000  CP0877
 84  0283   9104  0  1  1  2  0  0  0165  0296  0000  0157  0000  0000  CP0910
 85  0165   9104  0  0  1  1  0  0  0283  0296  0000  0134  0000  0000  CP0910
 86  0296   9109  0  0  2  0  2  0  0218  0000  0000  0165  0283  0000  CP0910
 87  0218   9324  1  0  1  1  1  0  0288  0000  0000  0296  0000  0000  CP0932
 88  0288   9325  1  0  2  1  1  0  0166  0000  0000  0218  0000  0000  CP0932
 89  0174   9509  0  0  1  2  0  0  0166  0071  0000  0000  0000  0000  CP0951
 90  0166   9509  0  0  1  1  0  0  0071  0174  0000  0288  0000  0000  CP0951
 91  0071   9514  0  0  2  0  2  0  0285  0000  0000  0174  0166  0000  CP0951
 92  0285   9885  0  0  1  0  2  0  0266  0237  0000  0071  0000  0000  CP0988
 93  0237   9890  0  0  2  1  0  0  0255  0000  0000  0266  0285  0000  CP0988
 94  0266   9890  0  1  2  2  0  0  0000  0000  0000  0237  0285  0000  CP0988
 95  0255  10317  1  0  1  1  2  0  0144  0000  0000  0237  0000  0000  CP1031
 96  0144  10318  1  0  2  1  2  0  0202  0000  0000  0255  0000  0000  CP1031
 97  0202  10547  0  0  1  0  2  0  0146  0106  0000  0144  0000  0000  CP1056
 98  0146  10573  0  0  2  1  0  0  0147  0000  0000  0202  0106  0000  CP1056
 99  0106  10573  0  1  2  2  0  0  0128  0000  0000  0146  0202  0000  CP1056
100  0128  10672  0  1  1  2  0  0  0180  0147  0000  0106  0000  0000  CP1067
101  0147  10673  0  0  1  1  0  0  0180  0128  0000  0146  0000  0000  CP1067
102  0180  10677  0  0  2  0  2  0  0263  0000  0000  0128  0147  0000  CP1067
103  0263  10917  1  0  1  1  2  0  0211  0000  0000  0180  0000  0000  CP1091
104  0211  10918  1  0  2  1  2  0  0291  0000  0000  0263  0000  0000  CP1091
105  0291  11195  0  0  1  0  2  0  0101  0179  0000  0211  0000  0000  CP1119
106  0101  11201  0  0  2  1  0  0  0177  0000  0000  0179  0291  0000  CP1119
107  0179  11201  0  1  2  2  0  0  0127  0000  0000  0101  0291  0000  CP1119
108  0127  11316  0  1  1  2  0  0  0177  0221  0000  0179  0000  0000  CP1131
109  0177  11316  0  0  1  1  0  0  0127  0221  0000  0101  0000  0000  CP1131
110  0221  11321  0  0  2  0  2  0  0068  0000  0000  0177  0127  0000  CP1131
111  0068  11613  1  0  1  1  1  0  0076  0000  0000  0221  0000  0000  CP1161
112  0076  11616  1  0  2  1  1  0  0216  0000  0000  0068  0000  0000  CP1161
113  0216  11914  1  0  1  1  1  0  0206  0000  0000  0076  0000  0000  CP1191
114  0206  11915  1  0  2  1  1  0  0158  0000  0000  0216  0000  0000  CP1191
115  0158  12250  0  0  1  0  2  0  0109  0118  0000  0206  0000  0000  CP1225
116  0109  12255  0  0  2  1  0  0  0067  0000  0000  0158  0118  0000  CP1225
117  0118  12255  0  1  2  2  0  0  0139  0000  0000  0158  0109  0000  CP1225
118  0139  12348  0  1  1  2  0  0  0058  0067  0000  0118  0000  0000  CP1235
119  0067  12348  0  0  1  1  0  0  0058  0139  0000  0109  0000  0000  CP1235
120  0058  12353  0  0  2  0  2  0  0156  0000  0000  0067  0139  0000  CP1235
121  0156  12517  1  0  1  1  2  0  0204  0000  0000  0058  0000  0000  CP1251
122  0204  12518  1  0  2  1  2  0  0124  0000  0000  0156  0000  0000  CP1251
123  0124  13032  0  0  1  0  2  0  0108  0113  0000  0204  0000  0000  CP1303
124  0108  13038  0  0  2  1  0  0  0288  0000  0000  0113  0124  0000  CP1303
125  0113  13038  0  1  2  2  0  0  0000  0000  0000  0108  0124  0000  CP1303
126  0288  13512  1  0  1  1  2  0  0273  0000  0000  0108  0000  0000  CP1351
127  0273  13513  1  0  2  1  2  0  0132  0000  0000  0288  0000  0000  CP1351
128  0132  13881  0  0  1  0  2  0  0168  0150  0000  0273  0000  0000  CP1388
129  0150  13886  0  0  2  1  0  0  0164  0000  0000  0132  0168  0000  CP1388
130  0168  13886  0  1  2  2  0  0  0111  0000  0000  0132  0150  0000  CP1388
131  0111  13993  0  1  1  2  0  0  0256  0164  0000  0168  0000  0000  CP1399
132  0164  13993  0  0  1  1  0  0  0256  0111  0000  0150  0000  0000  CP1399
133  0256  13999  0  0  2  0  2  0  0046  0000  0000  0164  0111  0000  CP1399
134  0046  14414  1  0  1  1  2  0  0209  0000  0000  0256  0000  0000  CP1441
135  0209  14415  1  0  2  1  2  0  0235  0000  0000  0046  0000  0000  CP1441
136  0235  14870  0  0  1  0  2  0  0142  0269  0000  0209  0000  0000  CP1487
137  0269  14875  0  0  2  1  0  0  0182  0000  0000  0235  0142  0000  CP1487
138  0142  14875  0  1  2  2  0  0  0250  0000  0000  0235  0269  0000  CP1487
139  0250  14983  0  1  1  2  0  0  0182  0051  0000  0142  0000  0000  CP1498
140  0182  14983  0  0  1  1  0  0  0051  0250  0000  0269  0000  0000  CP1498
141  0051  14988  0  0  2  0  2  0  0148  0000  0000  0182  0250  0000  CP1498
142  0148  15201  1  0  1  1  2  0  0229  0000  0000  0051  0000  0000  CP1520
143  0229  15202  1  0  2  1  2  0  0201  0000  0000  0148  0000  0000  CP1520
144  0201  15552  1  0  1  1  2  0  0242  0000  0000  0229  0000  0000  CP1555
145  0242  15553  1  0  2  1  2  0  0276  0000  0000  0201  0000  0000  CP1555
146  0276  15655  1  0  1  1  2  1  0295  0000  0000  0242  0000  0000  CP1565
147  0295  15656  1  1  2  1  2  0  0000  0000  0000  0276  0000  0000  CP1565
```

HOST TRACK MODEL

FIGURE B-3

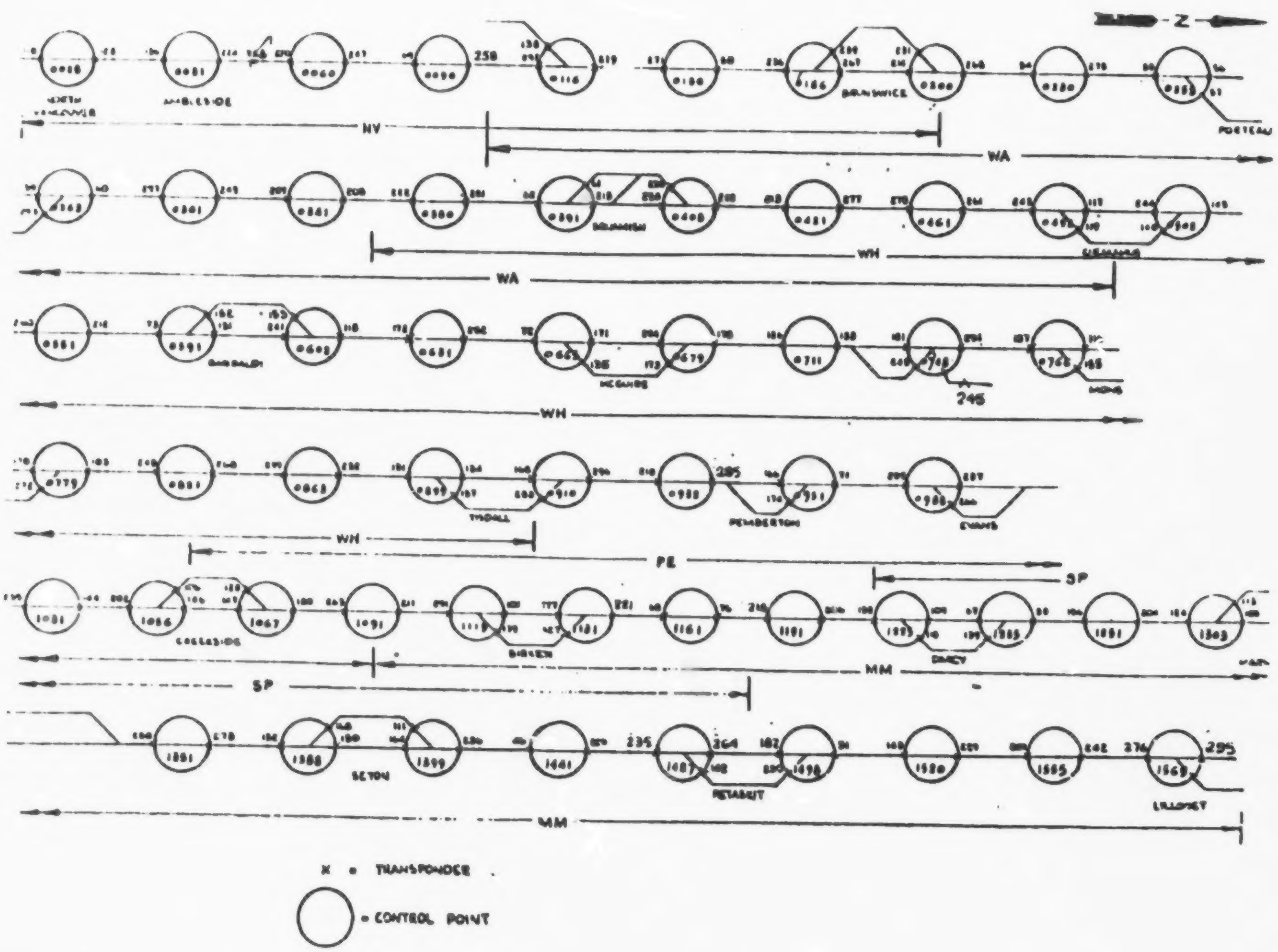

Z
AMBLESIDE
258
BRUNSWICK
PORTEAU
NV
WA
SQUAMISH
WH
WA
GARIBALDI
MCGUIRE
245
MONS
WH
295
PEMBERTON
EVANS
WH
PE
SP
BIRKEN
DARCY
MM
SP
235
364
182
276
295
SETON
RETASKIT
LILLOOET
MM
x = TRANSPONDER
= CONTROL POINT

FIGURE B-4

LIC TRACK MODEL SQUAMISH SUB-DIVISION

APPENDIX C

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

GLENAYRE DIGITRAC SPECIFICATION

SYSTEM DESCRIPTION

The Glenayre Digitrac System provides a means of data transfer between moving vehicles and the wayside. The data transfer occurs at fixed point locations precisely defined by the position of the equipment. It is designed primarily to provide location information from the wayside to a locomotive, but can be used on any vehicle provided the path of travel of the vehicle can be closely controlled. The flow of information is in one direction. This manual describes the system configuration for which the direction of information flow is from the wayside to the vehicle. An alternative configuration with information flow from the vehicle to the wayside is described in a supplementary volume, GL6000-002.

The mechanical design of the equipment is rugged and suitable for the rigors of a transportation industry environment. It will withstand extremes of temperature, weather, and vibration. It has been used over a wide range of operating conditions in railroad and rapid transit applications. Powerful data acquisition techniques assure reliable and secure data transfer at vehicle speeds from zero to over 160 kph.

The system has been designed for flexibility of use and its output can readily be interfaced to other display, recording, or processing equipment. Applications include vehicle location, speed control, electronic sentry, route control, and trip recording.

The system utilizes four types of equipment:

(1) 6110 Transponder

(2) 6215 Interrogator

(3) 6502 Controller

The block diagram in Figure 1 shows the system configuration of these elements.

The transponder is a small hermetically sealed unit which transmits digital data only when inductively energized. It is normally mounted on the wayside roadbed at fixed point locations. The transponder has a data capacity of four fixed decimal digits, giving a possible ten thousand unique codes, which can be used to define ten thousand unique locations.

The 6215 Interrogator is a rugged hermetically sealed unit which is normally mounted on the underside of the vehicle. It continuously generates and broadcasts a low power electromagnetic field at 200 kHz. When a transponder enters this field, its circuitry is energized and it transmits a modulated signal in the HF radio band. This signal is picked up by a receiving antenna located in the interrogator and is passed to the 6502 Controller.

The 6502 Controller is a ruggedized microprocessor-based data acquisition and control unit. It interfaces to the vehicle power directly and provides complete protection against input transients. The power for the 6215 Interrogator is supplied through the 6502 Controller. The received transponder data signal is demodulated in the Controller and checked for integrity. Data protection is provided by powerful BCH error check coding which virtually eliminates erroneous number acceptance. After data verification, the validated transponder number is available at the output interface in binary form. The interface is serial RS-232-C compatible.

Specifications

6110 Transponder

Temperature:	-55 to +70 deg. C storage -40 to +70 deg. C operating
Power Requirements:	None Power by Inductive Coupling
Operating Range:	25 to 60 cm from Interrogator (10 to 24 in.)
Environment:	Unaffected by snow,ice,dirt,water. May be fully immersed.
Data Capacity:	4 Decimal Digits
Data Selection:	Fixed at time of manufacture.

Data Transmission:	Low power HF near-field propogation. Complies with FCC Rules, Sec. 15 RF Carrier Freq: 27.255 MHz +0.01% RF Amplitude Modulation 50 to 60% DPSK Data Sub-Carrier: 25 KHz +5% Data Rate: 25k Baud +5%
Dimensions:	38L x 20W x 2H cm (15 x 8 x .75 in.)
Weight:	1.4 kb (3 lbs.)

6215 Interrogator

Temperature:	-55 to +70 deg. C storage -40 to +60 deg. C operating
Power Requirements:	Supplied by 6502 Controller 55 to 85V DC 0.25A Max.
Operating Range:	25 to 60 cm from Transponder (10 to 24 in.)

Note: Two interrogators may not be placed closer than 3 meters (10 feet) if one or both are operating.

Environment:	Unaffected by snow,ice,dirt,water. No conductive materials may be placed between Interrogator and Transponder or within 15 cm of Interrogator.

Power Transmission: Near field inductive coupling. Complies with FCC Rules, Sec. 15 Power frequency 200 kHZ +5%

Dimensions: 86L x 39W x 8H cm (34 x 15 x 3 in.)

Weight: 6.8 kg (15 lbs.)

6502 Controller

Temperature: -55 to +70 deg. C storage
-18 to +55 deg. C operating

Power Requirements: 55 to 85V DC 0.5A Max.

Environment: Suitable for physical and electrical environment of a locomotive.

Output Interface: EIA RS-232-C Type Z Serial Asynchronous

Output Data Format: Binary Coded Decimal

Dimensions: 41L x 29W x 9H cm (16 x 11.5 x 3.5 in.)

Weight: 5.5 kg (12 lbs.)

APPENDIX D

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

COMMUNICATIONS ANALYSIS

BRITISH COLUMBIA RAILWAY

COMMUNICATIONS DENSITY ANALYSIS

To determine the limitations on the existing communications, a system consisting of twenty trains was investigated over a ten minute interval. The average speed of these trains was eighteen mph. Control points are located every four miles and are delimited by two transponders. It is assumed initially that communications traffic may occur at only radio site and the total scan time is calculated. Then two sites with equal traffic density are assumed.

Three classes of periodic messages make up the majority of the traffic between the ELU/CLU's and the master station. These are: 1) polling requests and replies every 30 seconds, 2) reporting transponders crossed, 3) adding and/or removing authorized control points into/from the authorized control point list. The effect of messages which may be sent at random (speak-up, call dispatcher, etc.) are not considered.

Assume that communications protocol used for 1) and 2) above are the REQUEST 1, REQUEST 2, STATUS 1, and STATUS 2 used in the prototype system. For adding and deleting instructions stored in the ELU a complete handshake is proposed (the complete control point description is sent and echoed). These formats are subject to change, however, if it is felt that changes to the message format will not significantly increase the message length.

Communications Times

1) For the normal poll REQUEST 1 is sent, consisting of 4 bytes; and STATUS 1 is received, consisting of 12 bytes.

   20 trains have a total of 40 CLU/ELU's
   in 10 minutes, 40 units x 2 polls/minute x 10 minutes

   = 800 requests are made

   this takes $\left(\frac{16 \text{ bytes}}{30 \text{ bytes/sec}} + 100 \text{ msec turn on}\right) \times 800$

   = 8.5 minutes

2) When a transponder is crossed, STATUS 2 is sent by the ELU/CLU which adds 8 bytes to the STATUS 1 reply. REQUEST 2 is sent as a confirmation, adding 8 bytes to REQUEST 1. Therefore, for each transponder crossed, an extra 16 bytes will be added to the normal polling sequence.

20 trains travelling at 18 mph will travel a total of

$$20 \times 18 \text{ mph} \times \frac{10 \text{ minutes}}{60 \text{ minutes/hr}} = 60 \text{ miles}$$

therefore, a total of $\frac{60}{4} = 15$ control points will be crossed.

Each control point is marked by two transponders and each transponder will be reported twice, once by the engine and again by the caboose.

therefore, $2 \times 2 \times 15 = 60$ transponders will be reported

taking $\frac{16 \text{ bytes}}{30 \text{ bytes/sec}} \times 60$ transponders = 32 sec or 0.5 min

3) For each control point crossed, the master may send another instruction to the ELU. For this analysis it is assumed that a confirm before execut technique is used for the addition of an instruction to the list in the ELU. The sequence is:

i) The master sends the control point number, direction, route, and corresponding transponders to be ELU. This takes:

4	bytes header
4	bytes point number
12	bytes direction and route (5 characters for direction and 4 for route)
8	bytes for two transponder numbers which indicate when the instruction is fulfilled
28	bytes

ii) The ELU stores this information in a temporary buffer, rebuilds the message, and transmits it back to the master. This adds another 28 bytes to the sequence.

iii) The master checks the data in the ELU's reply and if correct, sends and "add to list" code to the ELU. This adds another 4 bytes to the sequence.

Therefore, for each control point crossed, a total of 28 + 28 + 4 bytes must be sent for each instruction added to the list in the ELU. In the ten minute period 15 control points will be crosssed and, on average, 15 instructions will be sent to the ELU.

This will take $\frac{60\ \text{bytes/instruction}}{30\ \text{bytes/second}}$ x 15 control points

= 30 seconds or 0.5 minutes

The total time to acquire the data from 20 trains, assuming no transmission errors, is:

Regular Poll	8.5
Transponder Reports	0.5
Instructions Sent	0.5
	9.5 Seconds

Effects of Communications Errors

It is assumed that when the ELU responds with an error response message or does not respond at all to the master, the master will repeat its transmission to the ELU. The master will allow a maximum of one re-try per train per attempt.

Dual Scanning

Since each radio site has a separate communications channel, sites which do not have an overlapping radio coverage can be accessed simultaneously. For this report, it is assumed that the equipped trains are equally divided between sites which do not have overlapping radio coverage. (Note: North Vancouver and Squamish are accessed through sites one and two respectively which overlap between miles 12 and 22. This may affect the above assumption).

Summary

The following table summarizes the effects of various levels of communication performance (95% and 70% levels are chosen since 95% reception may be possible while 70% was the reported performance on the prototype system) and single and dual access to the ELU/CLU's.

Time to Report 10 Minutes Data

Communications Response	One Site (minutes)	Two Sites (minutes)
100%	9.5	4.75
95%	10	5
70%	13.6	6.8

Conclusion

From the above figures, we can conclude that by accessing two ELU/CLU's at a time, 40 ELU/CLU's can be accessed with at least 30% spare capacity to allow for the miscellaneous message (speak-up, instruction remove, calibrate, etc.) not considered in this report.

Notes On Communications Density

This report develops a general formula relating the length of time radio traffic is being carried at a radio site to the number of trains accessed through the site, the average speed of the trains, the message lengths of the various transmissions, the data rate used, the transmitter turn-on times, and the average number of control points encountered. Typical values of track parameters are chosen and the relationship of the number of trains versus communications time is plotted for various values of average train speed.

Very General Communications Formula

Time for Poll

$$\left[\left(\frac{\#\text{char}}{\text{data rate}}\right) + \text{RSU}_{\text{turn-on}} + \text{ELU}_{\text{turn-on}}\right] \times T \times (\#\text{ units/train}) \times (\#\text{polls/hour})$$

Time for Reporting Transponders

$$\left[\left(\frac{\#\text{ char}}{\text{data rate}}\right) + \text{RSU}_{\text{turn-on}} + \text{ELU}_{\text{turn-on}}\right] \times (\#\text{transponders/mile}) \times \text{Speed} \times \text{trains} \times \frac{\#\text{ units}}{\text{trains}}$$

Time to Add Instruction to List in ELU

$$\left[\left(\frac{\#\text{char}}{\text{data rate}}\right) + \text{RSU}_{\text{turn-on}} + \left(\frac{\#\text{char echo}}{\text{data rate}}\right) + \text{ELU}_{\text{turn-on}} + \left(\frac{\#\text{char execute code}}{\text{data rate}}\right) + \text{RSU}_{\text{turn-on}}\right] \times \frac{\#\text{CPs}}{\text{mile}} \times \text{Speed} \times \#\text{trains}$$

The following values will be assumed for this study.

Data Rate - 300 Baud or 30 Char/Sec

RSU Delay - 50 Msec
Turn-On

ELU Delay - 50 Msec
Turn-On

# Poll/Hour - 120

# Units/Train - 2

# Char in Polling Request and Regular Reply - 16

# Char to Report in Transponder and Confirm the Transmission - 24

# Char to add an instruction to the list in the ELU - 44

Control Points and Transponder on Prototype System

Site	#CP's	Trans	Mileage	Trans/Mile	CP's/Mile
6	23	38	40	.95	.575
5	9	13	15	.87	.6
4	6	10	10	1.0	.6
3	27	44	45	1.0	.6
2	21	37	35	1.06	.6
1	5	8	8	1.0	.625

Say: 2/3 CP's/Mile

= 1 1/3 Transponder/Mile to allow for extra transponders.

Substituting these values into the above equations gives:

Polling

$$\left[\left(\frac{16}{30}\right) + 50_{\text{msec}} + 50_{\text{msec}}\right] \times T \times 2 \times 120$$

or 152 T, say 160 T

Transponders

$$\left[\left(\frac{24}{30}\right) + 50_{\text{msec}} + 50_{\text{msec}}\right] \times \frac{4}{3} \times S \times T \times$$

or 2.4 ST

Instructions

$$\left[\left(\frac{44}{30}\right) + 50_{\text{msec}} + 50_{\text{msec}}\right] \times \frac{2}{3} \times S \times T$$

or .98 ST, say ST

Combining the above terms gives:

$$\begin{aligned}\text{Total communications time per hour} &= 3.4\ ST + 160\ T \\ &= T\ \ 3.4S + 160\end{aligned}$$

Analysis

With the proposed interrogation scheme, each ELU would be interrogated a maximum of two times in each thirty second scan interval. A communication failure would be declared if no response was received after a certain number of 30 second intervals. This allows for one quick re-try to allow for noise bursts and a longer interval to allow for interference of longer duration. This technique is relatively simply to implement and should give good performance with a small number of retries.

The 300 baud communications link will require minimal CPU overhead, therefore, the master computer can handle data transmissions on more than one site simultaneously. It seems safe to assume that at least two, and perhaps three, sites may be accessed simultaneously depending on overlapping radio coverage between radio sites. Therefore, if two sites are accessed simultaneously, at least 18 trains, travelling at an average speed of 40 mph with a communications performance of 75%, may be accessed. If the average speed drops to 30 mph, the number of trains increases to 22 trains.

An examination of the B.C. Rail timetable, effective 0001 December 17, 1978 shows that, for regularly scheduled trains, at no time are more than two trains within the coverage of any radio site. In fact, there are only two times a day when three trains are on the sub-division simultaneously (one at North Vanncouver and two at Lillooet). If this traffic is doubled, there will be at most six equipped trains on the sub-division at any time. With the same traffic pattern, we will be able to communicate with these trains if they averaged 40 mph and all the messages have to be retried.

Conclusion

It is our opinion that the communications system proposed should be adequate as long as the performance level is above 75% (i.e., 25% or less of the messages sent by central have to be retried), and the number of trains accessed through over-lapping radio sites does not exceed 22 trains travelling at an average speed of 30 mph.

APPENDIX E

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

BASIC TRACKING TEST PLAN

AND SAMPLE RESULTS

Scope

1. This document defines the basic tracking tests which must be performed with the delivery of the six (6) pre-production engine logic units and one DCP.
2. Two (2) basic standards must be met, environmental standards and operating standards. Environmental tests will be conducted by Glenayre Electronics and operating tests by B.C. Railway.

Applicable Documents

1. Functional specifications of the Location, Identification and Control System, Volume I and II, April, 1980, prepared by Datap Systems.
2. LIC System Train Subsystem Specification GL-2025-002 prepared by Glenayre Electronics.
3. Definition and application of a Base-Line LIC System using a Data Collection Processor, Issue 4 - GL-2025-001 prepared by Glenayre Electronics.
4. Schedule "A", Statement of Work, British Columbia Railway's contract with "Her Majesty the Queen", as defined by serial number OST78-00217.

Test Requirements

1. Schedule "A", Task 3 (c) and (d), of British Columbia Railway's contract requirements of the Work Statement dictates the following:
    (a) Develop and test the software for automatic tracking of LIC equipped trains throughout the Squamish Subdivision.

    (b) The software system shall be designed to maintain records of transponders successfully received, communications performance and odometer calibration and the location of each LICS train on the subdivision.

(c) Demonstrate the successful operation of the basic train tracking through operation, data collection, and evaluation of these functions during a trial period of at least one week.

(d) The initial installation will comprise of 6 pre-production engine logic units which will be installed in 3 engines and 3 cabooses. The three engines and cabooses will be tracked by a pre-production DCP model through the completely installed communication system.

(e) The one weeks successful demonstration will be fulfilled after each equipped unit has been tracked for seven (7) consecutive trips over the Squamish Subdivision.

(f) The M.U. valve feature on the first 3 engines will be disabled to allow multiple tracking within the same power consist.

2. Individual tests which must be documented are as follows:

Transponder Tests - each unit must report transponders 99.8% accurately for seven (7) consecutive trips over the Squamish Subdivision.

Communications Performance Tests - for each unit the following data must be recorded for seven (7) consecutive trips over the Squamish Subdivision. B.C. Railway unit number, date, time, group of trip, total messages transmitted, and the total responses received.

Odometer Calibration Tests - each of the equipped engine units will make seven (7) consecutive trips over the Squamish Subdivision and reports will be generated with the following data:

B.C. Railway unit number, data, time, group of trip, the location of each calibration and the calibration error at each calibration location.

Train Location Test - the train image shall consist of the odometer reading of the locomotive every five (5) minutes during the time the train is being tracked. The form of the image shall be a table of time and mileage. Cabooses will be tracked and imaged at last control point crossing.

In addition to the above mentioned tests, British Columbia Railway will conduct system loading tests with the first six (6) units. As additional units come on stream, the system loading test will increase up to a maximum of forty (40) units.

Test Plan

1. Transponder Tests - the transponder reporting information will be made available on the DCP events printer. This information will be manually transcribed into the required format.

   British Columbia Railway are responsible to conduct the tests and provide the statistics. If the 99.8% reporting is not achieved, Glenayre is responsible to determine why. If the problem can be traced to B.C. Railway's communications system, then B.C. Railway will assume responsibility.

   If B.C. Railway are satisfied that the problem can be corrected during the "REWORK" phase, then the tests will be considered complete.

2. Communications Test - a separate list of communications statistics will be compiled for each of the six (6) units. The information required will be:

   (a) Total number of transmissions for that trip.

   (b) Total number of responses received for that trip.

   (c) Total number of speak-up messages for that trip.

   (d) Individual site coverage statistics for that trip.

   The communications statistics are printed on the DCP events printer and will be manually transcribed into the required format. Glenayre are going to provide assistance by grouping this information at pre-determined intervals. B.C. Railway are responsible to conduct the tests and provide the finished statistical reports. In the event of unsatisfactory performance, B.C. Railway will be responsible to determine why.

3. Odometer Calibration Tests - a separate list of statistics will be compiled for each of the three (3) engines equipped. The information required wil be:

   (a) Speak-up at first transponder detected.

   (b) Infer direction at second transponder detected.

   (c) Calibrate odometer at third transponder which is at least one mile from second transponder.

   (d) The odometer will not be re-calibrated after initial calibration, but reference will be recorded at transponder crossings to actual known location versus odometer reading.

   This information will be recorded on the DCP events printer and will be retrieved and transcribed manually onto test form. B.C. Railway will be responsible for this task.

   In the event of unsatisfactory performance of the calibrate feature, Glenayre will be responsible to determine why and correct. Additional tests must then be conducted until proven.

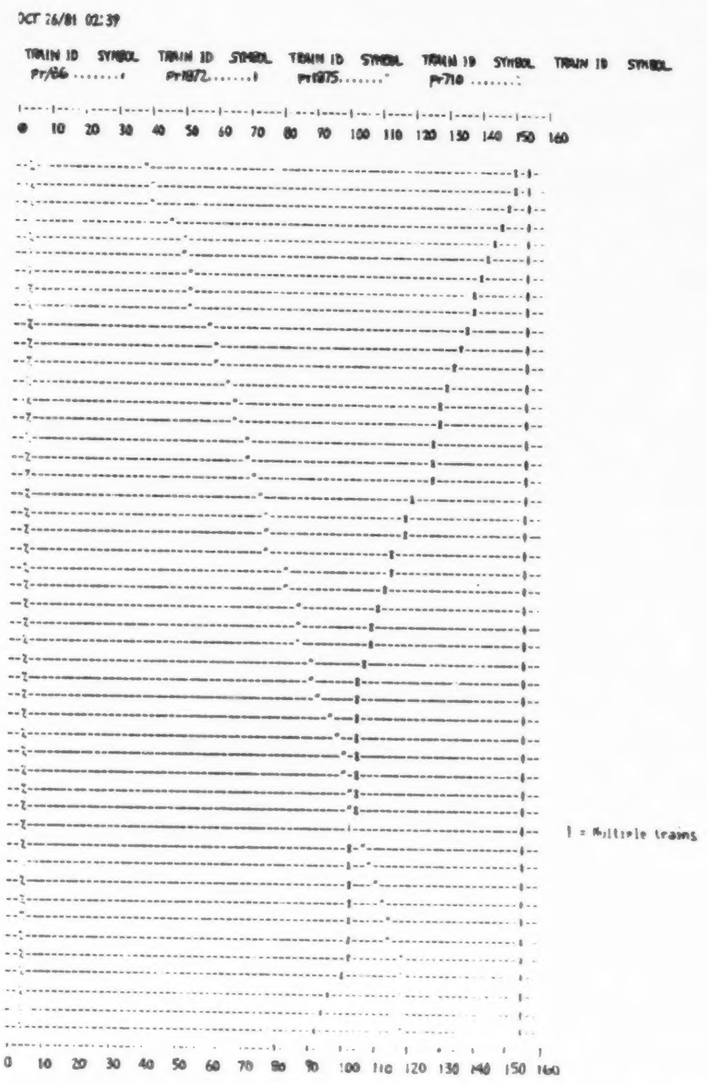
4. Train Location Tests - this test will be provided on a dedicated printer driven by the DCP, the printer will provide a time distance graph. Each of the six (6) units will be tracked over the subdivision. Engines will have their location stamped every five (5) minutes, cabooses will be identified at all control point crossings.

   B.C. Railway are responsible to gather the graphs and monitor the operation for correct reporting. In the event the train location tests are not satisfactory, it will become Glenayre's responsibility to determine why. Corrections must be made until statistics can be gathered as required.

5. System Loading Tests - all six (6) units will be included in one train. The communications link will be manually interrupted in each site coverage area. After sufficient time has lapsed to put all ELU's in communication failure, the link will be restored.

   The DCP must be capable of handling the six (6) speakups from each individual site.

If the test is unsatisfactory, it will be Glenayre's responsibility to determine why and correct. The test will then be re-run to confirm positive results as required.

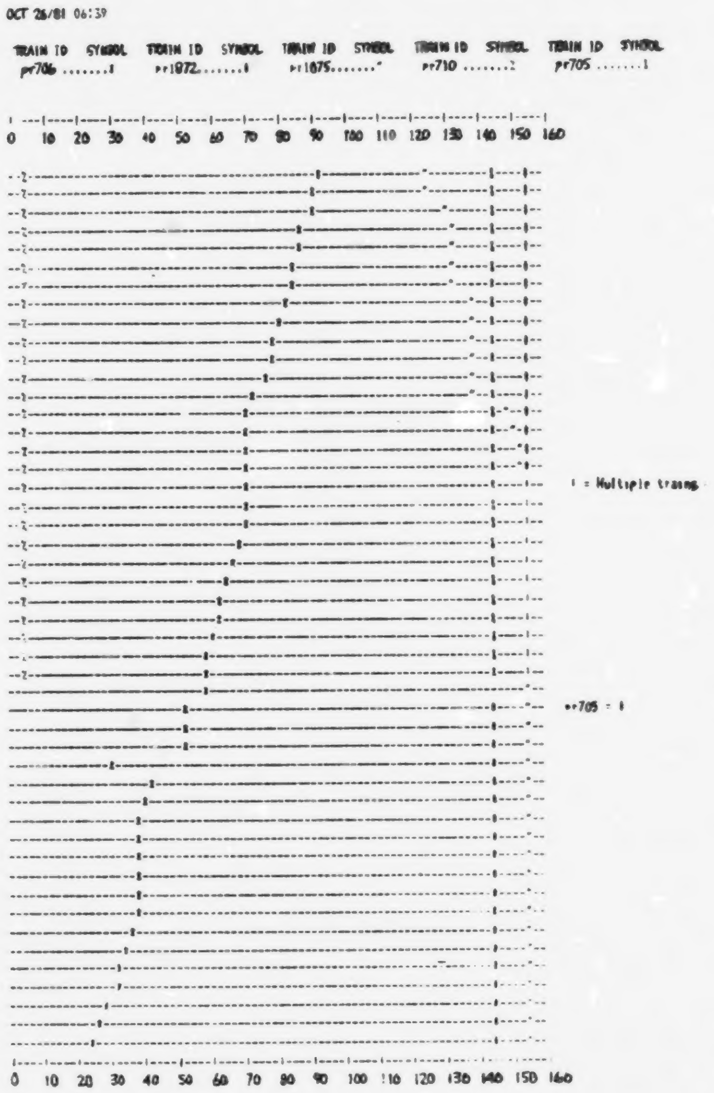


OCT 26/81 02:39

```
TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL
 Pr186 .......,     Pr1872......!      Pr1875.......'     Pr710 .......:
```

EXAMPLE OF DCP TRAIN GRAPH
PERFORMANCE DURING BASIC TRACKING

FIGURE E-1 (a)

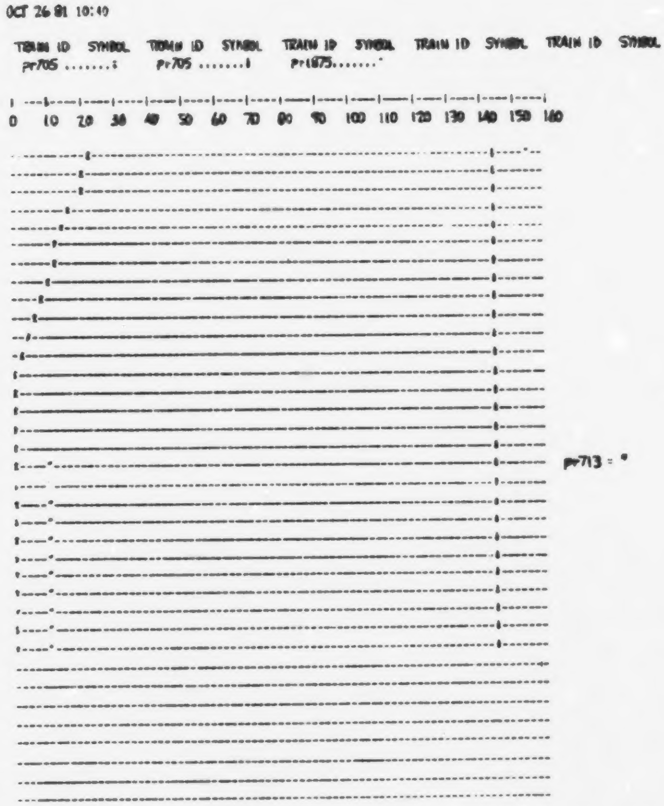


```
OCT 26/81 06:39

TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL
 pr706 .......!     pr1872.......!     pr1075......."     pr710 .......:     pr705 .......!
```

```
! = Multiple trains

pr705 = !
```

EXAMPLE OF DCP TRAIN GRAPH
PERFORMANCE DURING BASIC TRACKING

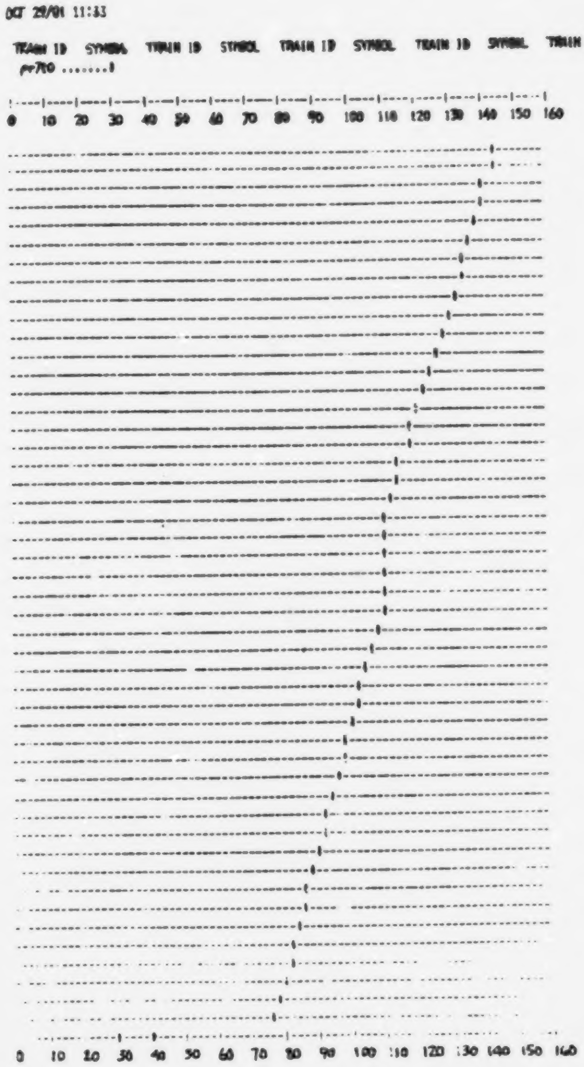
FIGURE E-1 (b)



```
OCT 26 81 10:40

TRAIN ID  SYMBOL  TRAIN ID  SYMBOL  TRAIN ID  SYMBOL  TRAIN ID  SYMBOL  TRAIN ID  SYMBOL
 pr705 .......:    Pr705 .......!    Pr1875.......'
```

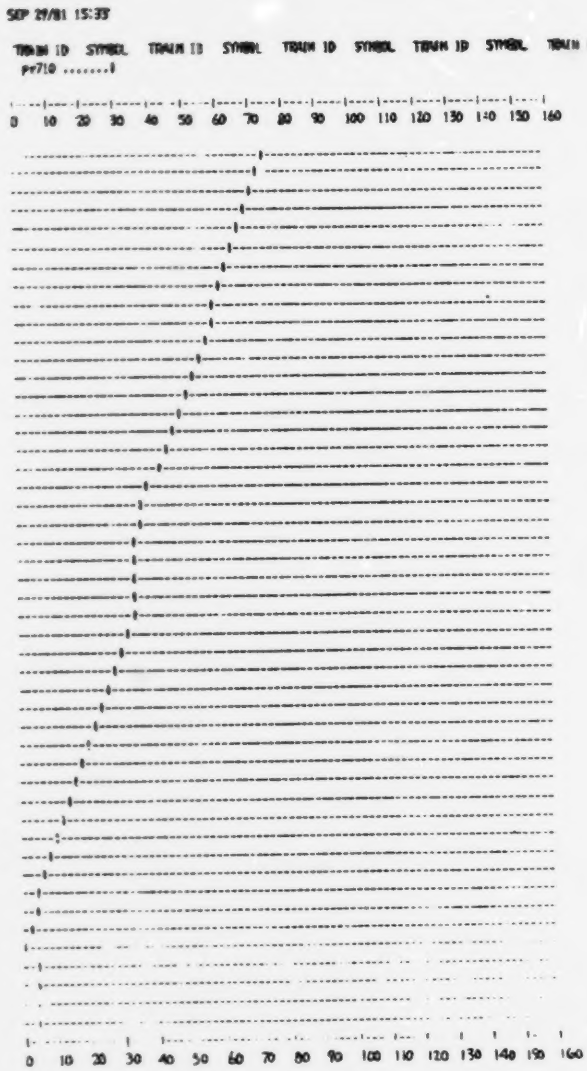
EXAMPLE OF DCP TRAIN GRAPH
PERFORMANCE DURING BASIC TRACKING

FIGURE E-1 (c)



EXAMPLE OF DCP TRAIN GRAPH
PERFORMANCE DURING BASIC TRACKING

FIGURE E-1 (d)



```
SEP 29/81 15:33

TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL   TRAIN ID  SYMBOL
 pr710 .......!
```

EXAMPLE OF DCP TRAIN GRAPH
PERFORMANCE DURING BASIC TRACKING

FIGURE E-1 (e)

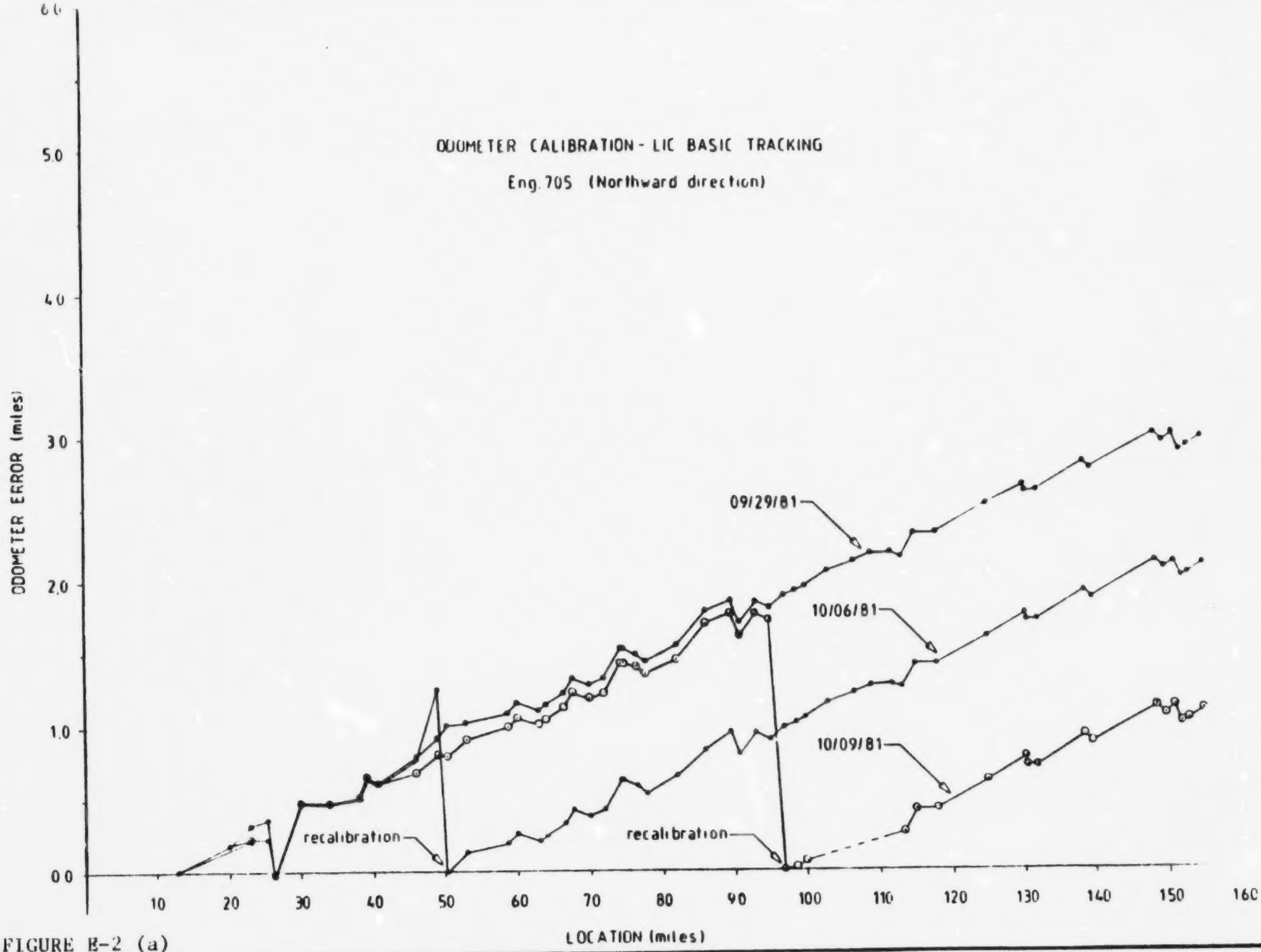

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 705 (Northward direction)
ODOMETER ERROR (miles)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
LOCATION (miles)
09/29/81
10/06/81
10/09/81
recalibration
recalibration

FIGURE E-2 (a)

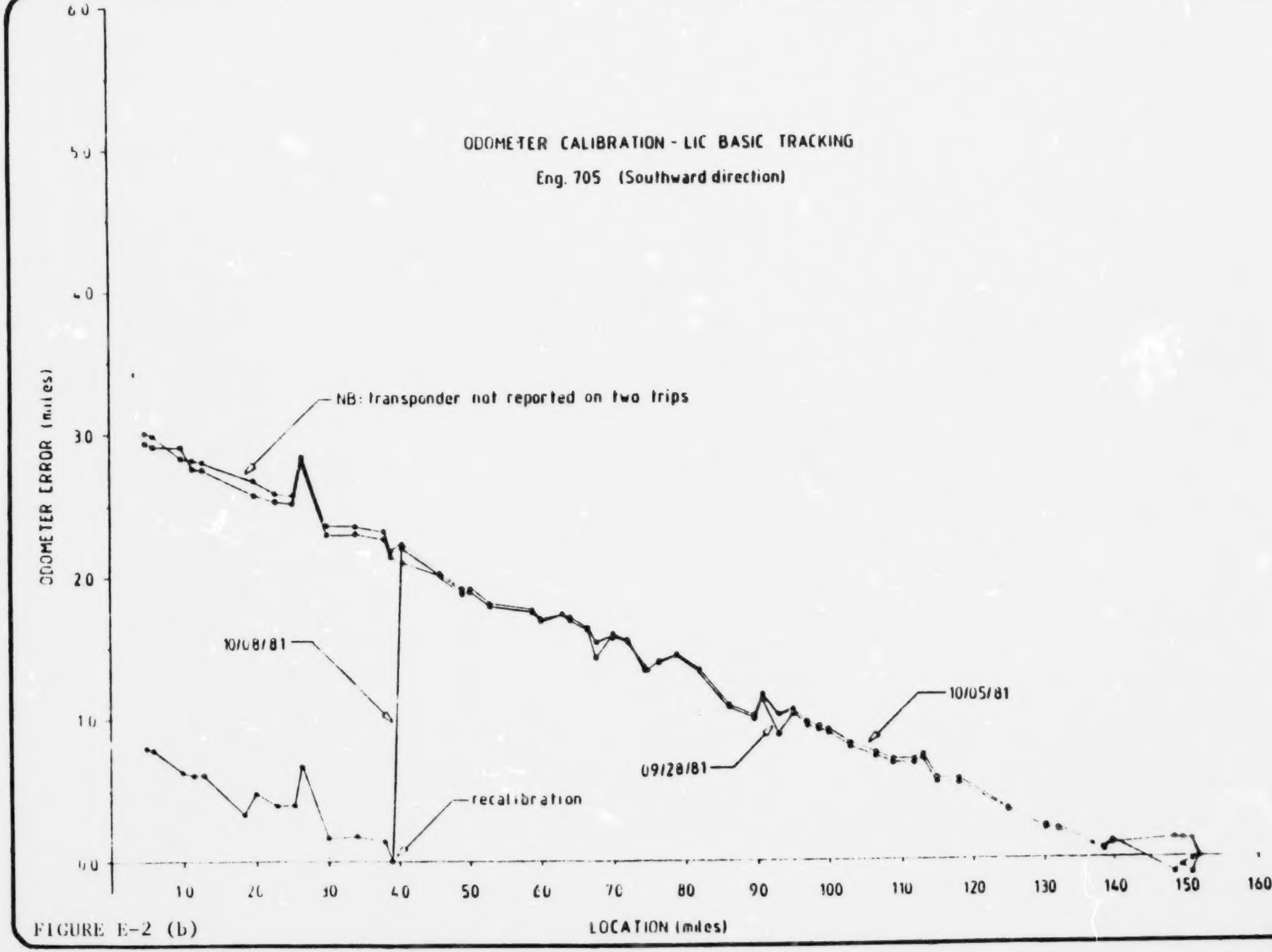

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 705 (Southward direction)
NB: transponder not reported on two trips
10/08/81
recalibration
09/28/81
10/05/81
ODOMETER ERROR (miles)
0.0
10
20
30
40
50
60
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
LOCATION (miles)

FIGURE E-2 (b)

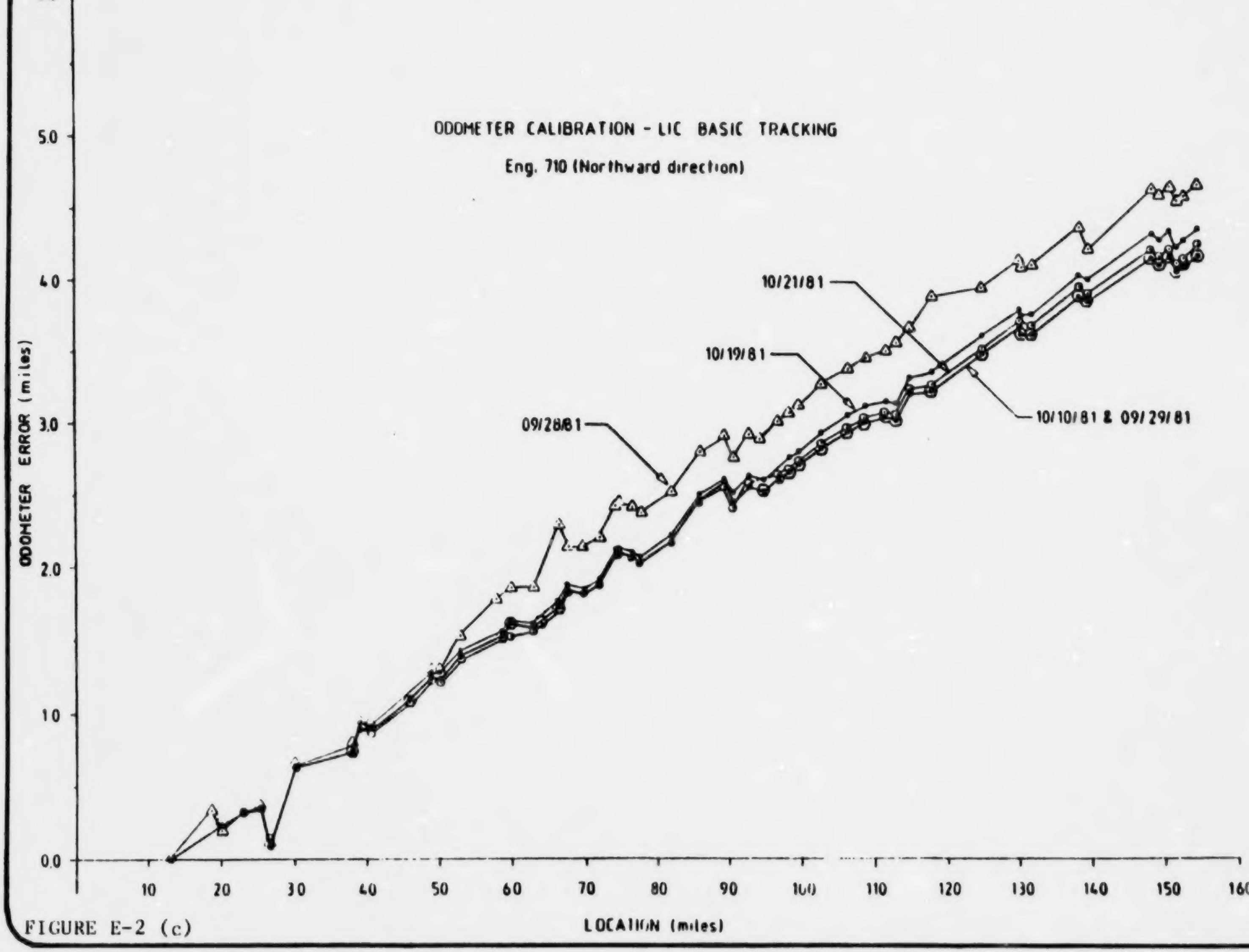

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 710 (Northward direction)
ODOMETER ERROR (miles)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
LOCATION (miles)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
09/28/81
10/19/81
10/21/81
10/10/81 & 09/29/81

FIGURE E-2 (c)

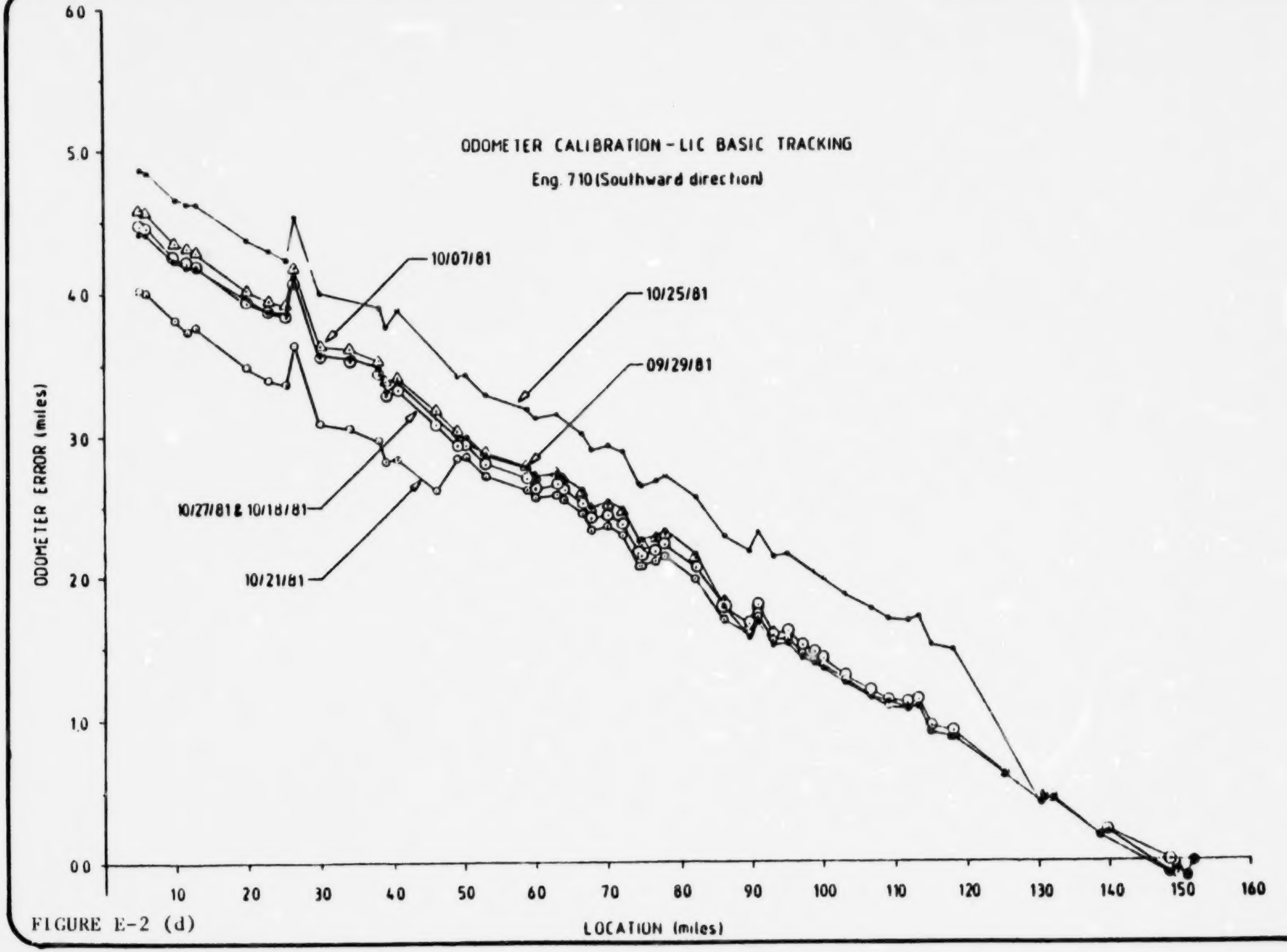

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 710 (Southward direction)
10/07/81
10/25/81
09/29/81
10/27/81 & 10/18/81
10/21/81
ODOMETER ERROR (miles)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
LOCATION (miles)

FIGURE E-2 (d)

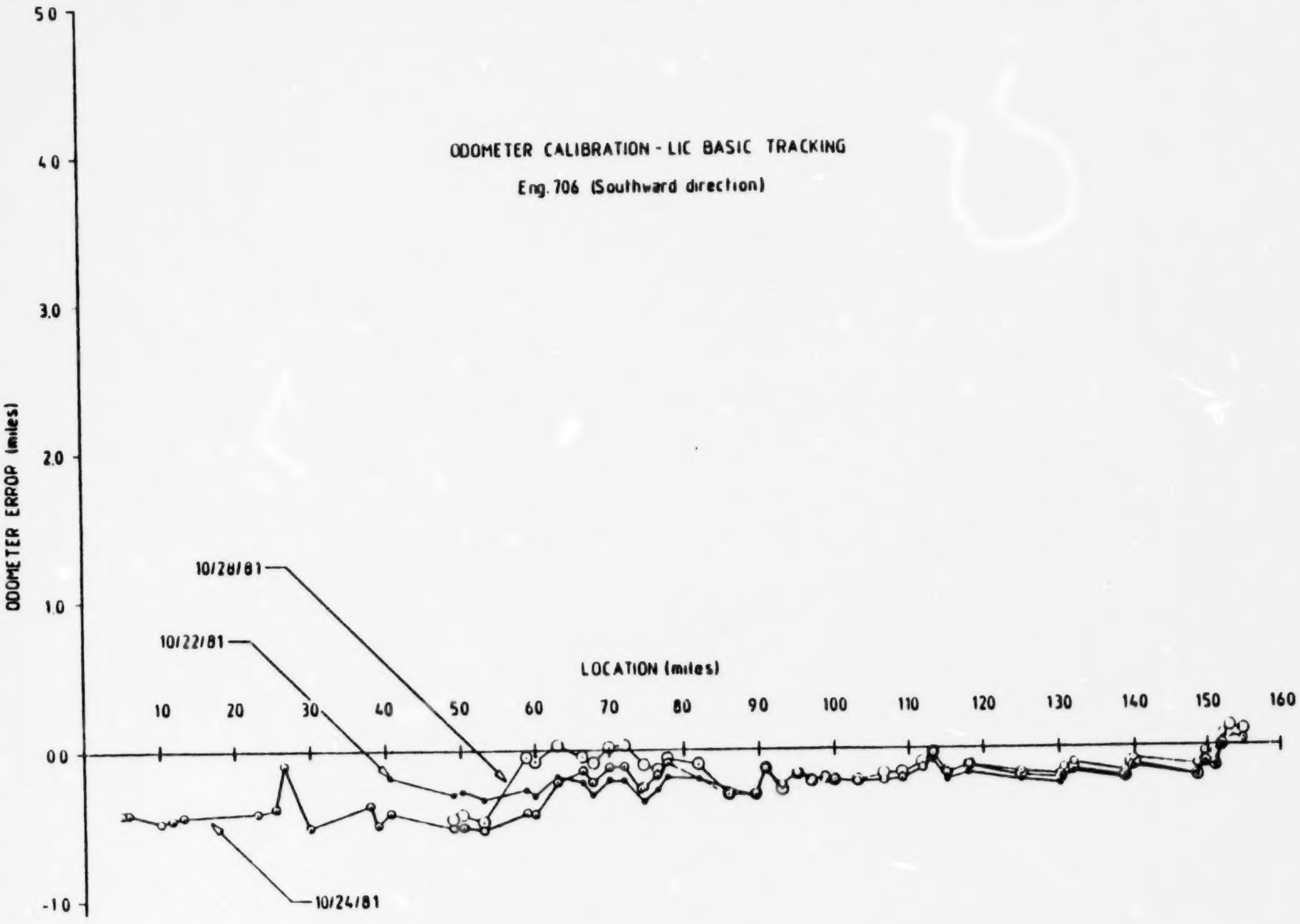

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 706 (Southward direction)
ODOMETER ERROR (miles)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
LOCATION (miles)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
10/28/81
10/22/81
10/24/81

FIGURE E-2 (e)

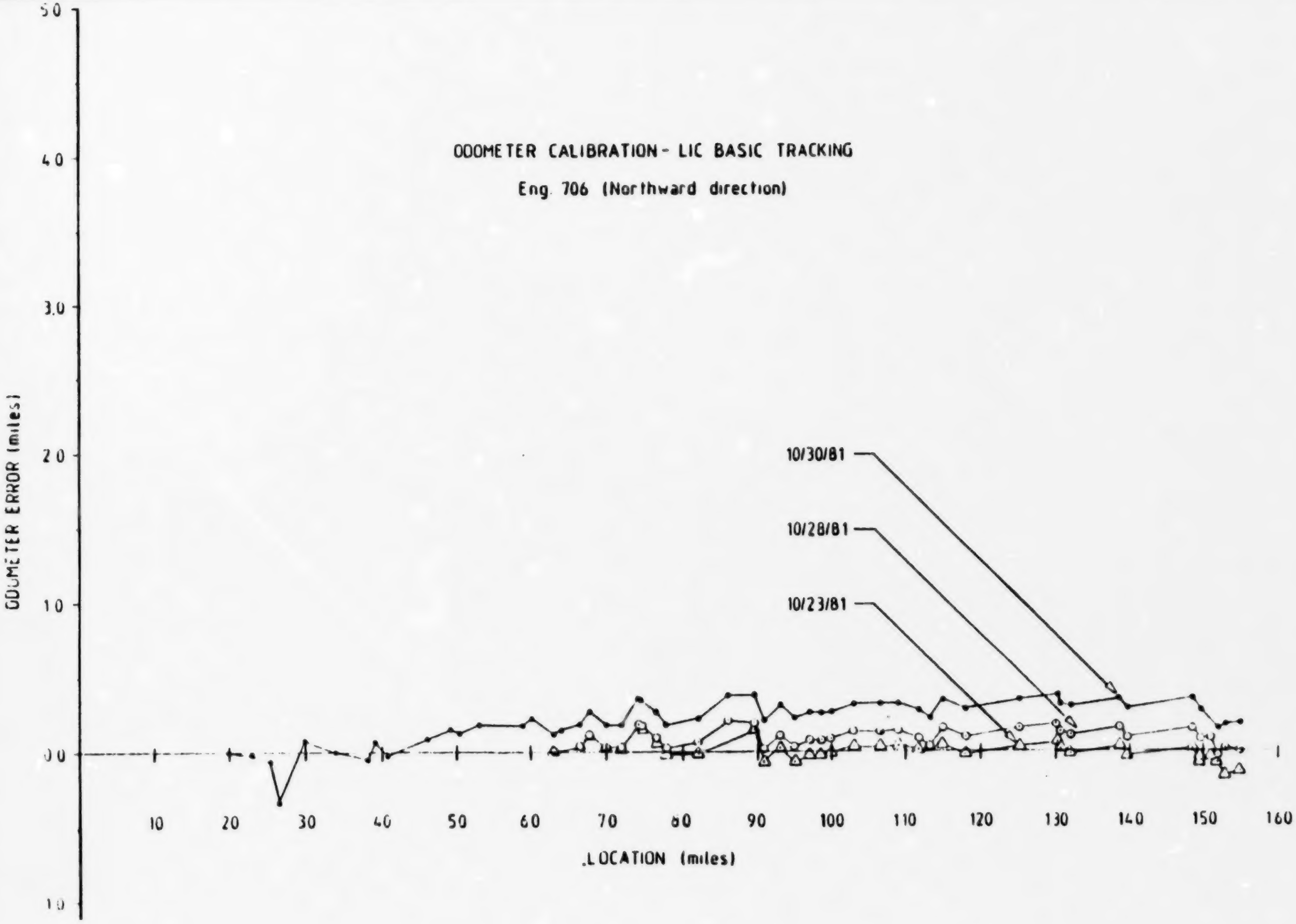

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 706 (Northward direction)
ODOMETER ERROR (miles)
5.0
4.0
3.0
2.0
1.0
0.0
1.0
LOCATION (miles)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
10/30/81
10/28/81
10/23/81

FIGURE E-2 (f)

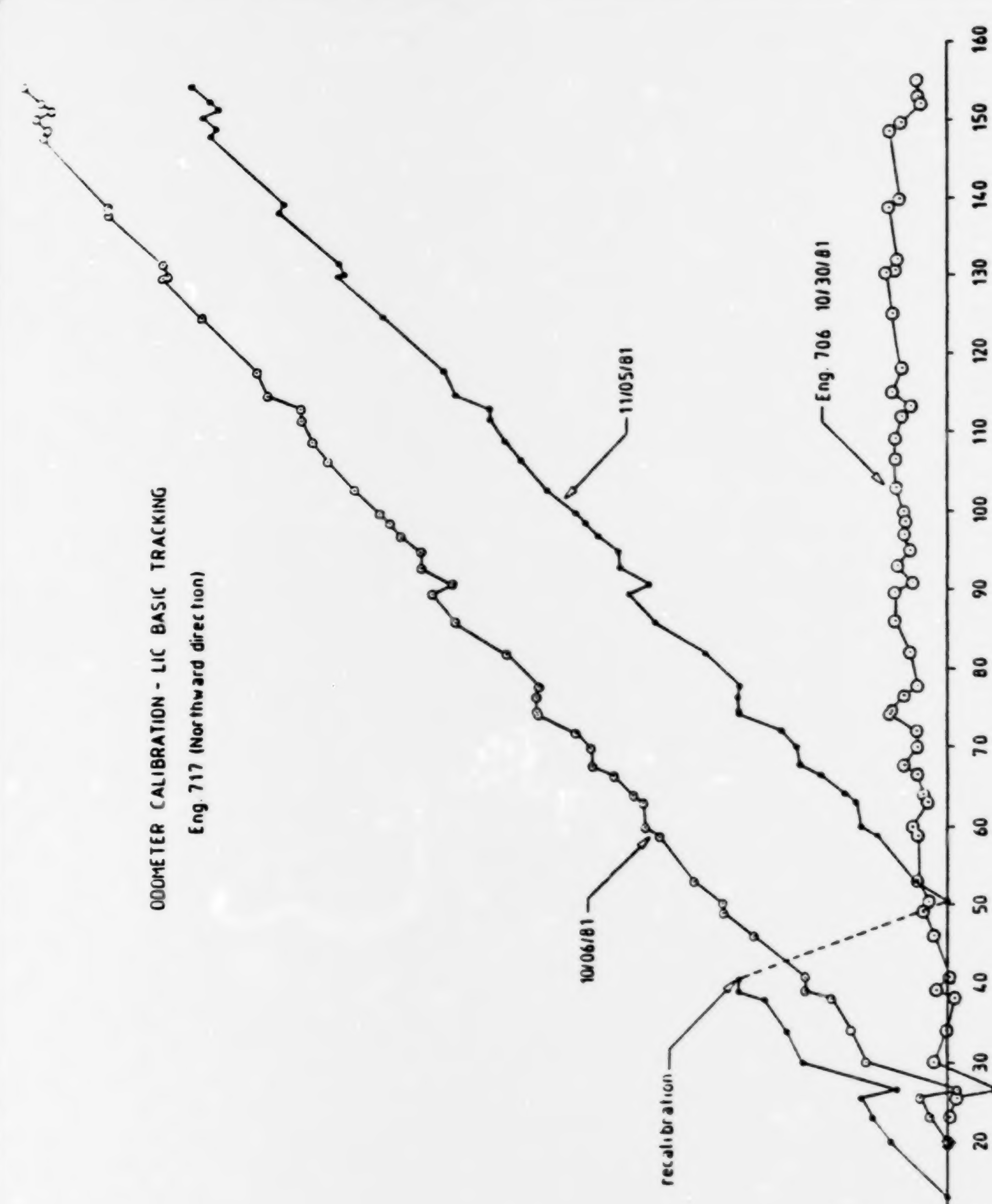

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng. 717 (Northward direction)
10/06/81
11/05/81
Eng. 706 10/30/81
recalibration
ODOMETER ERROR (miles)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
LOCATION (miles)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

FIGURE E-2 (g)

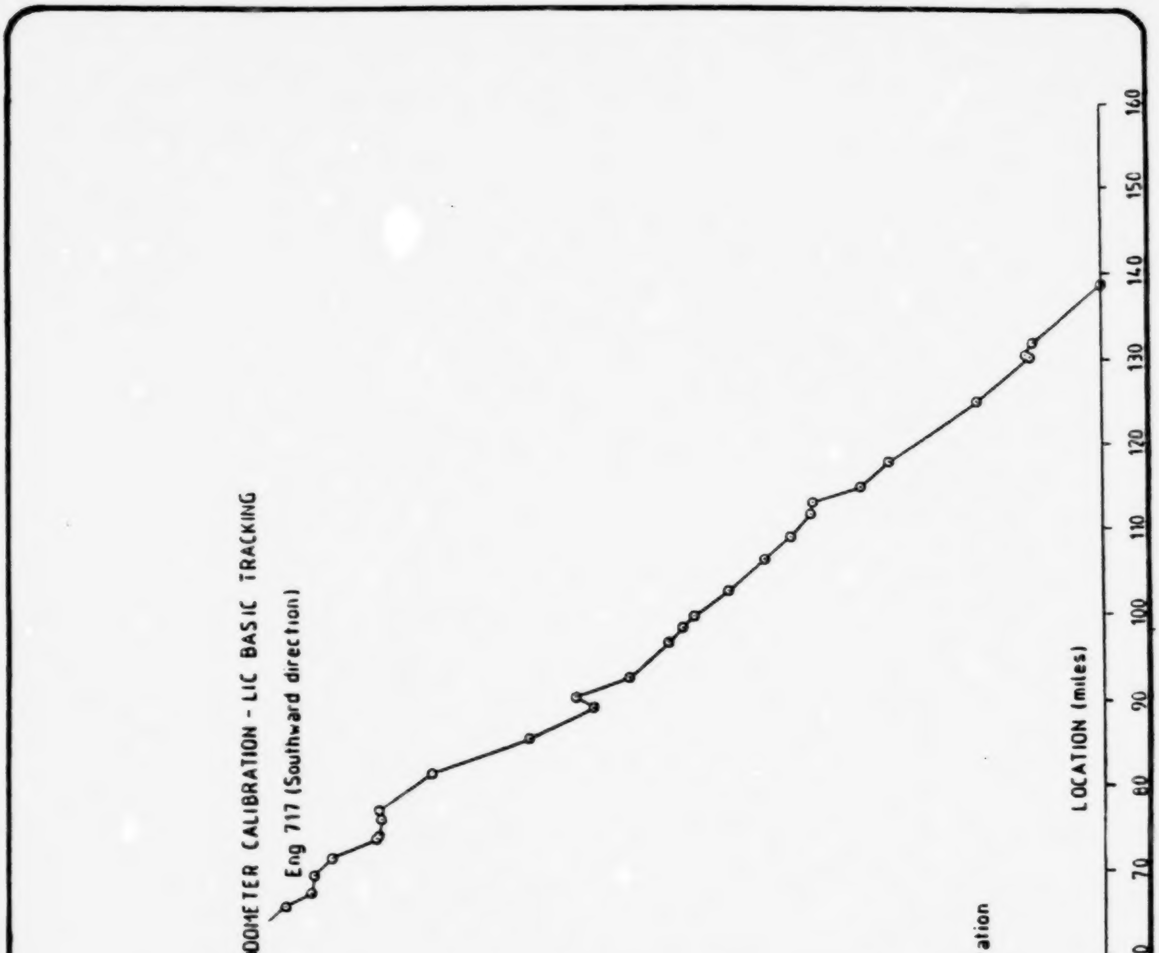
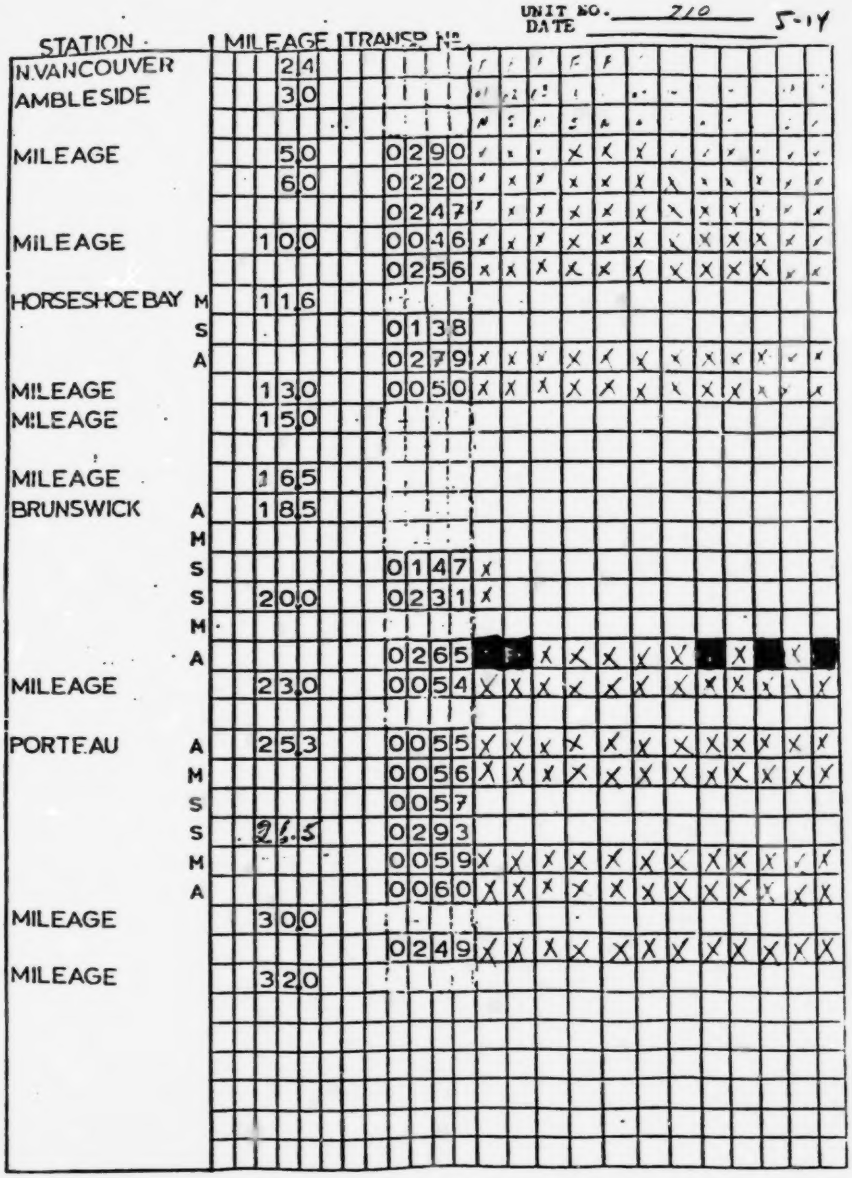

ODOMETER CALIBRATION - LIC BASIC TRACKING
Eng 717 (Southward direction)
recalibration
ODOMETER ERROR (miles)
LOCATION (miles)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

FIGURE E-2 (h)

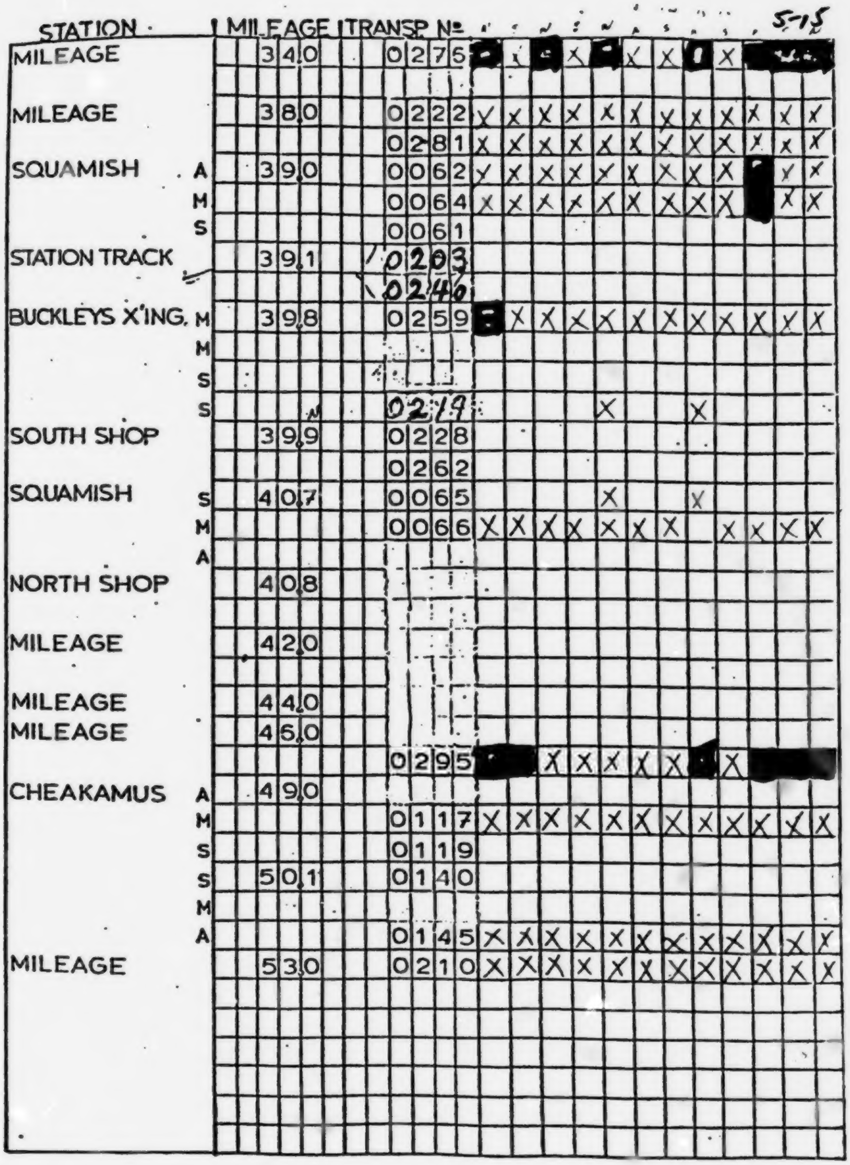


UNIT NO. 210 5-14
DATE

STATION		MILEAGE	TRANSP Nº												
N.VANCOUVER		24													
AMBLESIDE		30													
MILEAGE		5.0	0290	✓	✓	✓	X	X	X	✓	✓	X	✓	✓	✓
		6.0	0220	✓	X	X	X	X	X	X	X	X	X	X	X
			0247	✓	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		10.0	0046	X	X	X	X	X	X	X	X	X	X	X	X
			0256	X	X	X	X	X	X	X	X	X	X	X	X
HORSESHOE BAY	M	11.6													
	S		0138												
	A		0279	X	X	X	X	X	X	X	X	X	X	✓	X
MILEAGE		13.0	0050	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		15.0													
MILEAGE		16.5													
BRUNSWICK	A	18.5													
	M														
	S		0147	X											
	S	20.0	0231	X											
	M														
	A		0265	■	■	X	X	X	X	X	■	X	■	X	■
MILEAGE		23.0	0054	X	X	X	X	X	X	X	X	X	X	X	X
PORTEAU	A	25.3	0055	X	X	X	X	X	X	X	X	X	X	X	X
	M		0056	X	X	X	X	X	X	X	X	X	X	X	X
	S		0057												
	S	21.5	0293												
	M		0059	X	X	X	X	X	X	X	X	X	X	✓	X
	A		0060	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		30.0													
			0249	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		32.0													

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE BASIC TRACKING TRANSPONDER SUMMARY

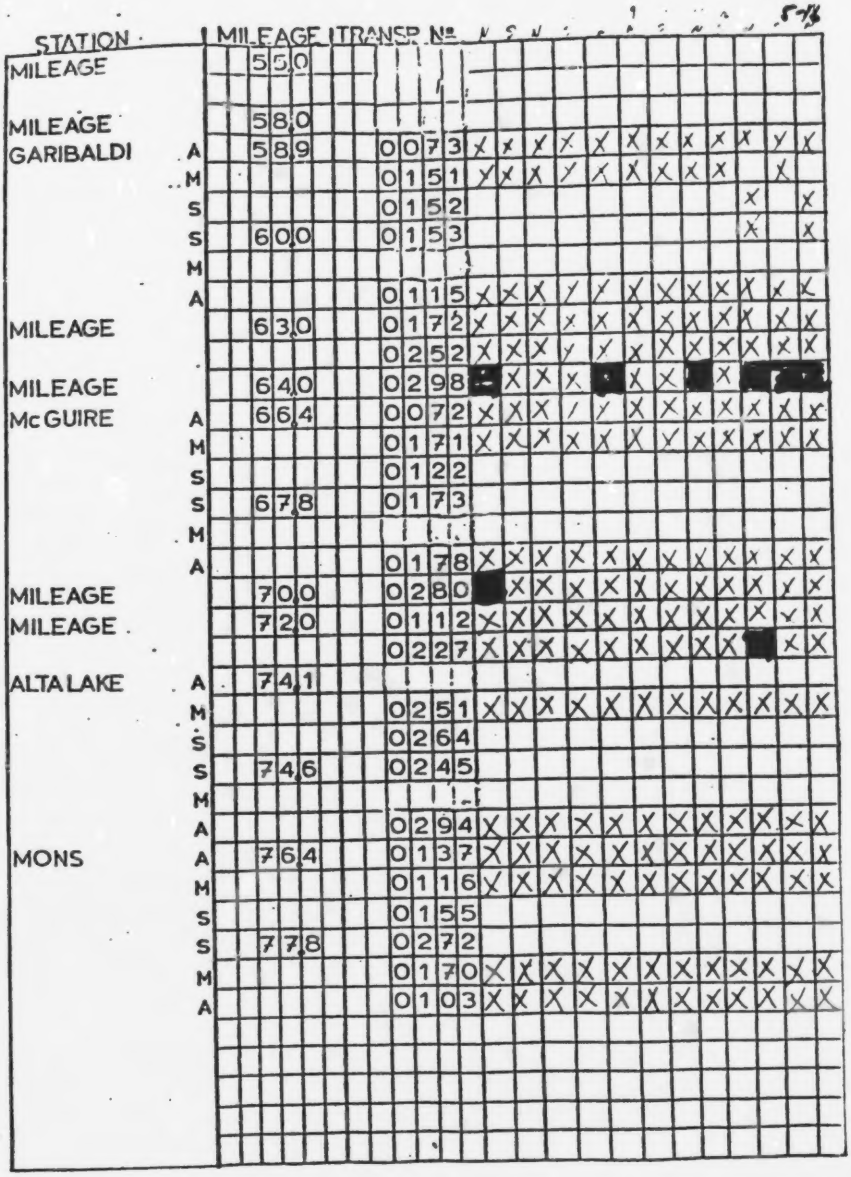
FIGURE E-3 (a)



STATION		MILEAGE	TRANSP Nº											5-15	
MILEAGE		34.0	0275	■	X	■	X	■	X	X	■	X	■	■	■
MILEAGE		38.0	0222	X	X	X	X	X	X	X	X	X	X	X	X
			0281	X	X	X	X	X	X	X	X	X	X	X	X
SQUAMISH	A	39.0	0062	X	X	X	X	X	X	X	X	X	■	X	X
	M		0064	X	X	X	X	X	X	X	X	X	■	X	X
	S		0061												
STATION TRACK		39.1	0203												
			0240												
BUCKLEYS X'ING.	M	39.8	0259	■	X	X	X	X	X	X	X	X	X	X	X
	M														
	S														
	S		0219					X			X				
SOUTH SHOP		39.9	0228												
			0262												
SQUAMISH	S	40.7	0065					X			X				
	M		0066	X	X	X	X	X	X	X		X	X	X	X
	A														
NORTH SHOP		40.8													
MILEAGE		42.0													
MILEAGE		44.0													
MILEAGE		46.0													
			0295	■	■	X	X	X	X	X	■	X	■	■	■
CHEAKAMUS	A	49.0													
	M		0117	X	X	X	X	X	X	X	X	X	X	X	X
	S		0119												
	S	50.1	0140												
	M														
	A		0145	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		53.0	0210	X	X	X	X	X	X	X	X	X	X	X	X

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE BASIC TRACKING TRANSPONDER SUMMARY

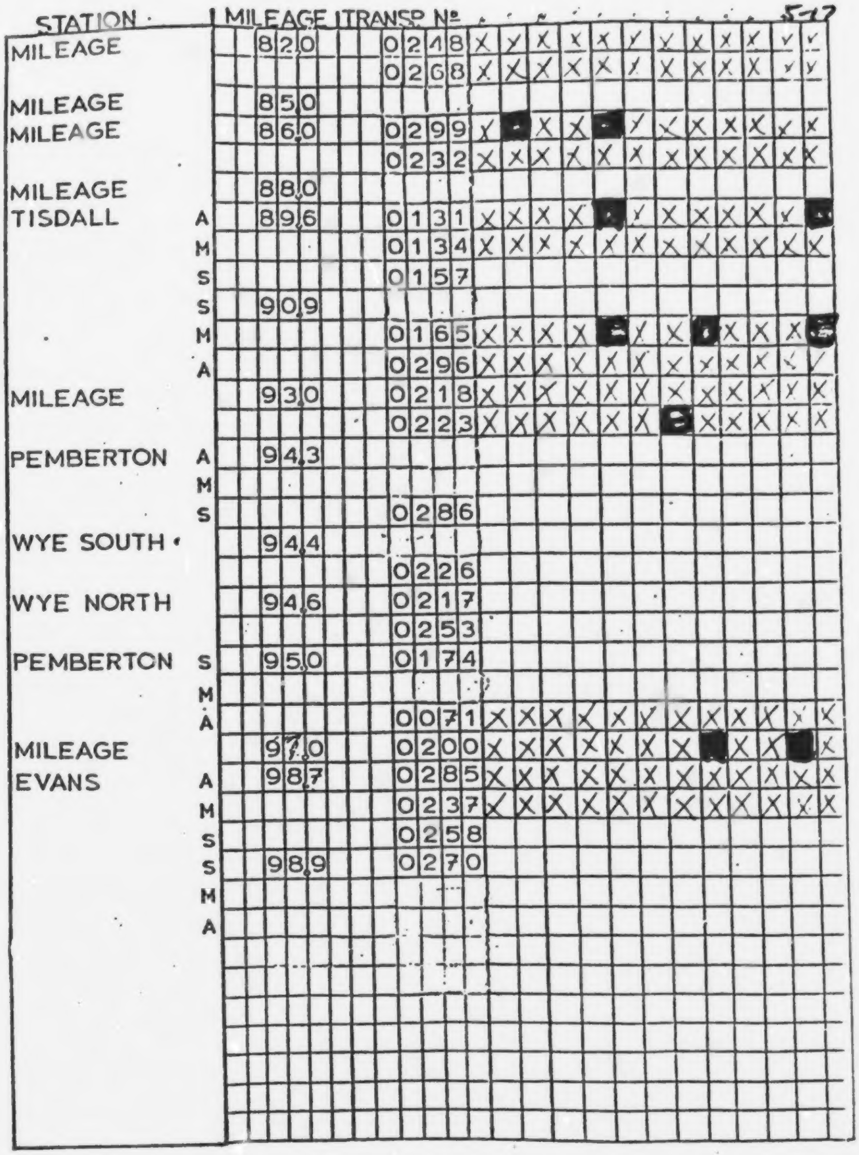
FIGURE E-3 (b)



STATION		MILEAGE	TRANSP. №												5-16
MILEAGE		55.0													
MILEAGE		58.0													
GARIBALDI	A	58.9	0073	X	X	X	X	X	X	X	X	X	X	✓	X
	M		0151	✓	X	X	✓	X	X	X	X	X		X	
	S		0152										X		X
	S	60.0	0153										X		X
	M														
	A		0115	X	X	X	✓	✓	X	X	X	X	X	X	X
MILEAGE		63.0	0172	X	X	X	X	X	X	X	X	X	X	X	X
			0252	X	X	X	✓	✓	X	X	X	X	X	X	X
MILEAGE		64.0	0298	■	X	X	X	■	X	X	■	X	■	■	■
McGUIRE	A	66.4	0072	X	X	X	/	✓	X	X	X	X	X	X	X
	M		0171	X	X	X	X	X	X	✓	X	X	X	X	X
	S		0122												
	S	67.8	0173												
	M														
	A		0178	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		70.0	0280	■	X	X	X	X	X	X	X	X	X	✓	X
MILEAGE		72.0	0112	X	X	X	X	X	X	X	X	X	X	✓	X
			0227	X	X	X	X	X	X	X	X	X	■	X	X
ALTA LAKE	A	74.1													
	M		0251	X	X	X	X	X	X	X	X	X	X	X	X
	S		0264												
	S	74.6	0245												
	M														
	A		0294	X	X	X	X	X	X	X	X	X	X	X	X
MONS	A	76.4	0137	X	X	X	X	X	X	X	X	X	X	X	X
	M		0116	✓	X	X	X	X	X	X	X	X	X	X	X
	S		0155												
	S	77.8	0272												
	M		0170	X	X	X	X	X	X	X	X	X	X	✓	X
	A		0103	X	X	X	X	X	X	X	X	X	X	X	X

EXAMPLE OF RAW TRANSPONDER DATA USED TO
COMPILE BASIC TRACKING TRANSPONDER SUMMARY

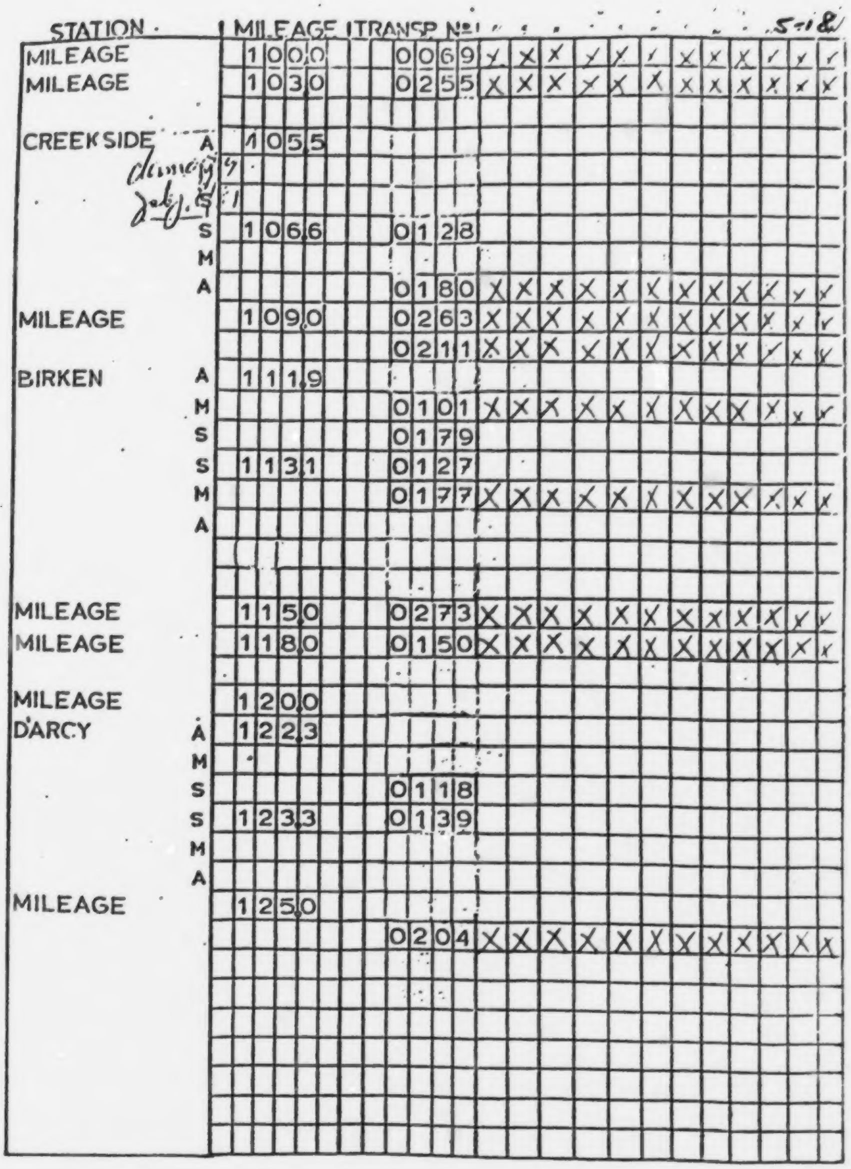
FIGURE E-3 (c)



STATION		MILEAGE	TRANSP. Nº												5-17
MILEAGE		82.0	0248	X	✓	X	X	X	✓	✓	X	X	X	✓	✓
			0268	X	X	X	X	X	✓	X	X	X	X	✓	✓
MILEAGE		85.0													
MILEAGE		86.0	0299	✓	■	X	X	■	✓	✓	X	X	X	✓	X
			0232	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		88.0													
TISDALL	A	89.6	0131	X	X	X	X	■	✓	X	X	X	X	✓	■
	M		0134	X	X	X	X	X	X	X	X	X	X	X	X
	S		0157												
	S	90.9													
	M		0165	X	X	X	X	■	✓	X	■	X	X	X	■
	A		0296	X	X	X	X	X	X	X	✓	X	X	✓	✓
MILEAGE		93.0	0218	X	X	X	X	X	X	X	X	X	X	X	X
			0223	X	X	X	X	X	X	■	X	X	X	X	X
PEMBERTON	A	94.3													
	M														
	S		0286												
WYE SOUTH		94.4													
			0226												
WYE NORTH		94.6	0217												
			0253												
PEMBERTON	S	95.0	0174												
	M														
	A		0071	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		97.0	0200	X	X	X	X	X	X	X	■	X	X	■	X
EVANS	A	98.7	0285	X	X	X	X	X	X	X	X	X	X	X	X
	M		0237	X	X	X	X	X	X	X	X	X	X	X	X
	S		0258												
	S	98.9	0270												
	M														
	A														

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE BASIC TRACKING TRANSPONDER SUMMARY

FIGURE E-3 (d)



STATION		MILEAGE	TRANSP Nº												5-18
MILEAGE		100.0	0069	✓	X	X	✓	✓	✓	X	X	X	✓	✓	✓
MILEAGE		103.0	0255	X	X	X	✓	X	X	X	X	X	X	X	✓
CREEKSIDE	A	105.5													
damaged	7														
July. 5	1														
	S	106.6	0128												
	M														
	A		0180	X	X	X	X	X	X	X	X	X	X	✓	✓
MILEAGE		109.0	0263	X	X	X	X	X	X	X	X	X	X	X	✓
			0211	X	X	X	✓	X	X	X	X	X	✓	X	✓
BIRKEN	A	111.9													
	M		0101	X	X	X	X	X	X	X	X	X	X	X	✓
	S		0179												
	S	113.1	0127												
	M		0177	X	X	X	X	X	X	X	X	X	X	X	X
	A														
MILEAGE		115.0	0273	X	X	X	X	X	X	X	X	X	X	✓	✓
MILEAGE		118.0	0150	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		120.0													
D'ARCY	A	122.3													
	M														
	S		0118												
	S	123.3	0139												
	M														
	A														
MILEAGE		125.0													
			0204	X	X	X	X	X	X	X	X	X	X	X	X

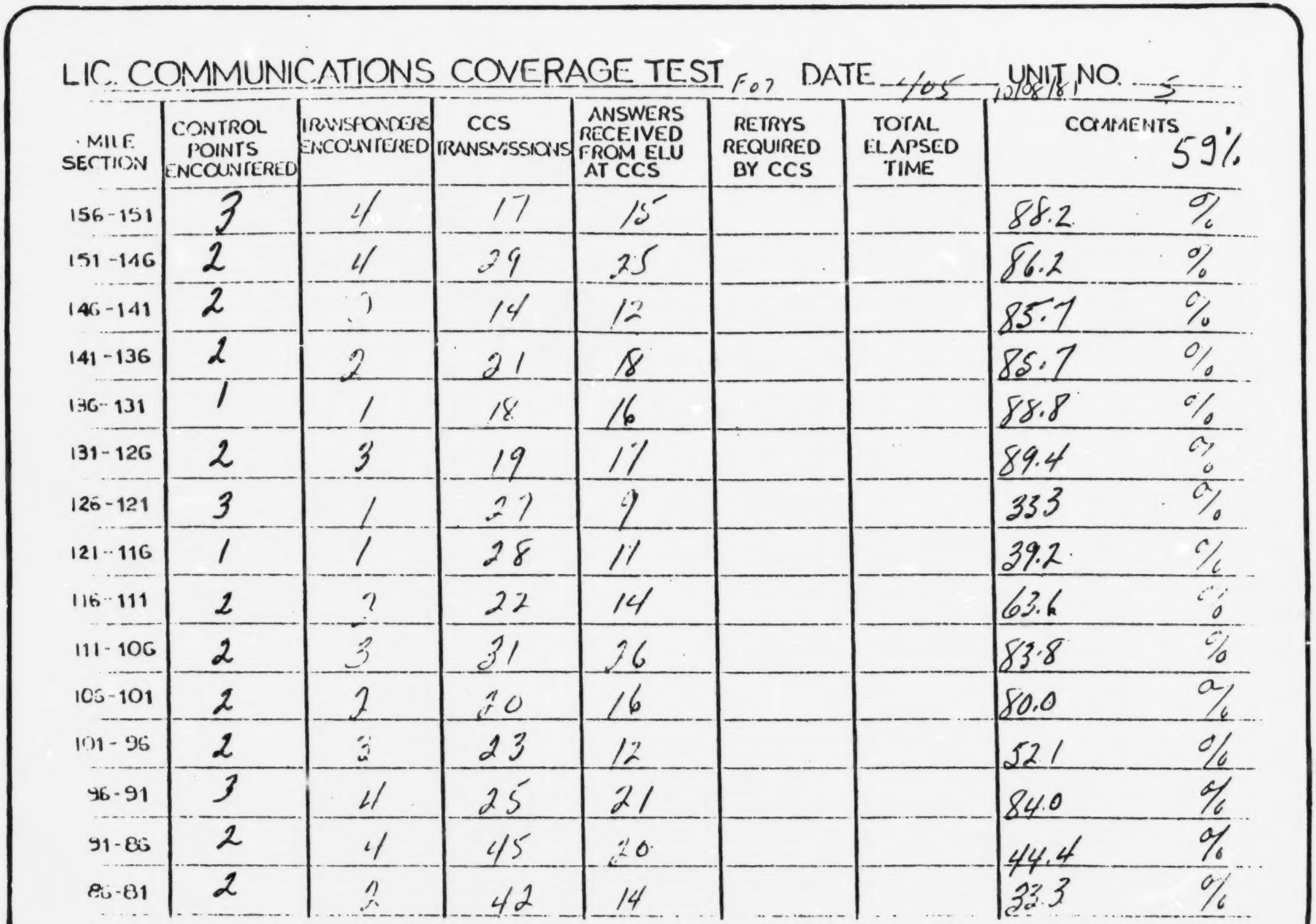
EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE BASIC TRACKING TRANSPONDER SUMMARY

FIGURE E-3 (e)

STATION		MILEAGE	TRANSP Nº	DATE											
MARNE	A	130.1	0124	X	X	X	X	X	X	X	X	X	X	X	X
	M		0108	X	X	X	X	X	X	X	X	X	X	X	X
	S		0113												
	S	130.5	0129												
	M		0175	X	X	X	X	X	X	X	X	X	X	X	X
	A														
MILEAGE		132.0	0288	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		135.0													
SETON	A	138.6	0132	X	X	X	X	X	X	X	X	X	X	X	X
	M														
	S		0168												
	S	139.8	0111												
	M		0164	X	■	X	X	X	X	X	X	X	X	X	X
	A														
MILEAGE		141.0													
MILEAGE		144.0													
RETASKIT	A	148.5	0135	X	X	X	X	X	X	X	X	X	X	X	X
	M														
	S		0142												
	S	149.7	0250												
	M		0182	X	X	X	X	X	X	X	X	X	X	X	X
	A		0051	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		151.0	0242	X	X	X	X	X	X	X	X	X	X	X	X
		152.0	0148	X	X	X	X	X	X	X	X	X	X	X	X
			0229	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		153.0	0221	X	X	X	X	X	X	X	X	X	X	X	X
MILEAGE		155.0	0201	X	X	X	X	X	X	X	X	X	X	X	X
LILLOOET	A	156.5													
	M														
	S														

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE BASIC TRACKING TRANSPONDER SUMMARY

FIGURE E-3 (f)



LIC. COMMUNICATIONS COVERAGE TEST F07 DATE 405 10/08/81 UNIT NO. 5

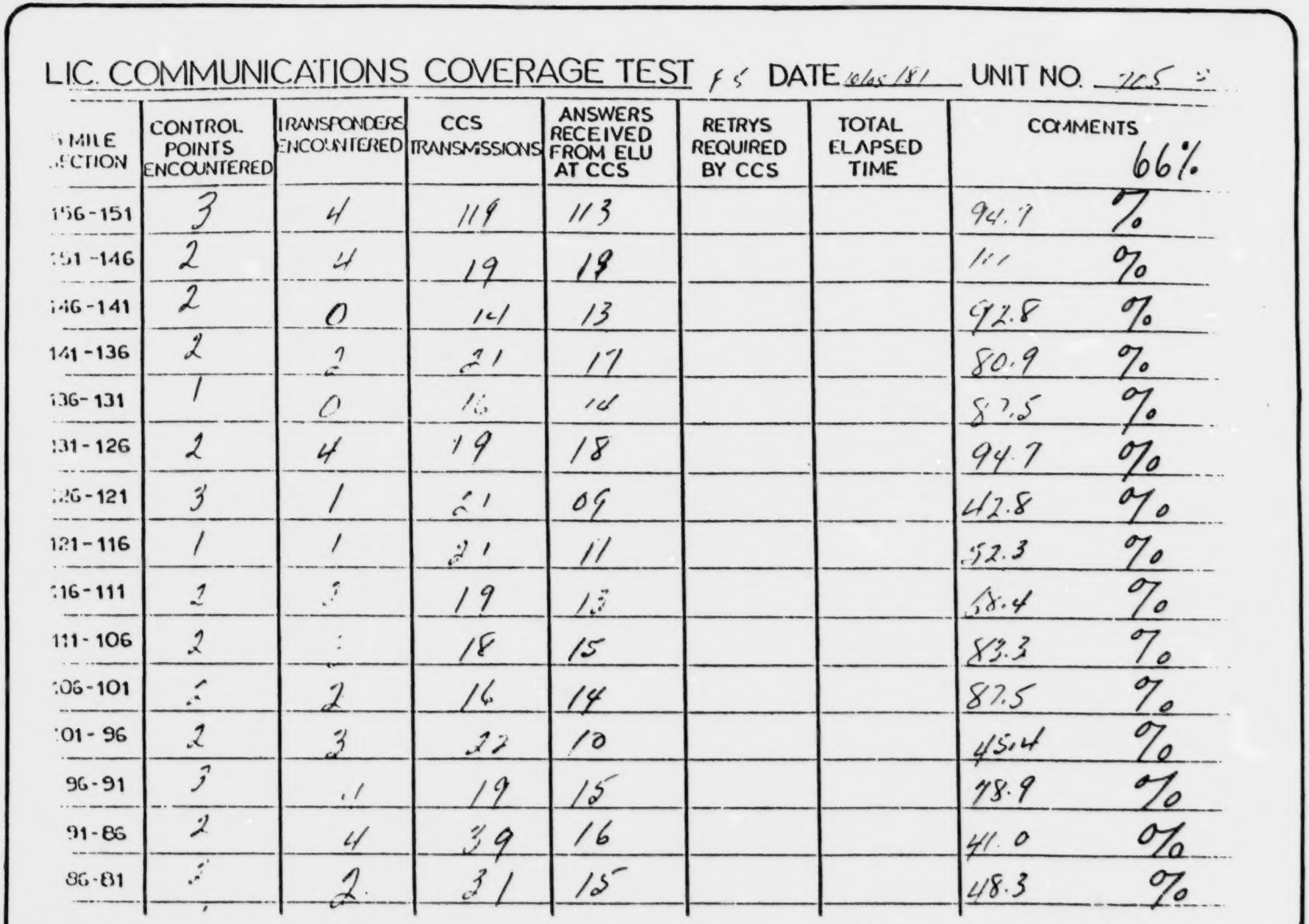
MILE SECTION	CONTROL POINTS ENCOUNTERED	TRANSPONDERS ENCOUNTERED	CCS TRANSMISSIONS	ANSWERS RECEIVED FROM ELU AT CCS	RETRYS REQUIRED BY CCS	TOTAL ELAPSED TIME	COMMENTS 59%
156-151	3	4	17	15			88.2 %
151-146	2	4	29	25			86.2 %
146-141	2	2	14	12			85.7 %
141-136	2	2	21	18			85.7 %
136-131	1	1	18	16			88.8 %
131-126	2	3	19	17			89.4 %
126-121	3	1	27	9			33.3 %
121-116	1	1	28	11			39.2 %
116-111	2	2	22	14			63.6 %
111-106	2	3	31	26			83.8 %
106-101	2	2	20	16			80.0 %
101-96	2	3	23	12			52.1 %
96-91	3	4	25	21			84.0 %
91-86	2	4	45	20			44.4 %
86-81	2	2	42	14			33.3 %

FIGURE E-4 (a) EXAMPLE OF RAW COMMUNICATIONS DATA USED TO COMPILE BASIC TRACKING COMMUNICATION SUMMARY

LIC. COMMUNICATIONS COVERAGE TEST f 6 DATE 10/26/81 UNIT NO. ~~405~~ N

MILE SECTION	CONTROL POINTS ENCOUNTERED	TRANSPONDERS ENCOUNTERED	CCS TRANSMISSIONS	ANSWERS RECEIVED FROM ELU AT CCS	RETRYS REQUIRED BY CCS	TOTAL ELAPSED TIME	COMMENTS 59%
156-151	3	6	38	33			86.8 %
151-146	2	1	33	31			93.9 %
146-141	2	1	51	38			74.5 %
141-136	2	2	41	37			90.2 %
136-131	1	3	31	31			100 %
131-126	2	1	31	27			82.0 %
126-121	3	6	31	23			74.1 %
121-116	1	2	34	20			58.8 %
116-111	2	2	38	34			89.4 %
111-106	2	3	31	25			80.6 %
106-101	2	2	32	24			75.0 %
101-96	2	4	31	25			80.6 %
96-91	3	5	45	37			82.2 %
91-86	2	4	72	23			31.9 %
86-81	2	2	65	21			32.3 %
81-76	1	4	30	28			93.3 %

FIGURE E-4 (b) EXAMPLE OF RAW COMMUNICATIONS DATA USED TO COMPILE BASIC TRACKING COMMUNICATION SUMMARY



LIC. COMMUNICATIONS COVERAGE TEST f s DATE [illegible] UNIT NO. 705

5 MILE SECTION	CONTROL POINTS ENCOUNTERED	TRANSPONDERS ENCOUNTERED	CCS TRANSMISSIONS	ANSWERS RECEIVED FROM ELU AT CCS	RETRYS REQUIRED BY CCS	TOTAL ELAPSED TIME	COMMENTS 66%
156-151	3	4	119	113			94.9 %
151-146	2	4	19	19			[illegible] %
146-141	2	0	14	13			92.8 %
141-136	2	2	21	17			80.9 %
136-131	1	0	16	14			87.5 %
131-126	2	4	19	18			94.7 %
126-121	3	1	21	09			42.8 %
121-116	1	1	21	11			52.3 %
116-111	2	3	19	13			68.4 %
111-106	2	[illegible]	18	15			83.3 %
106-101	2	2	16	14			87.5 %
101-96	2	3	22	10			45.4 %
96-91	3	4	19	15			78.9 %
91-86	2	4	39	16			41.0 %
86-81	3	2	31	15			48.3 %

FIGURE E-4 (c) EXAMPLE OF RAW COMMUNICATIONS DATA USED TO COMPILE BASIC TRACKING COMMUNICATION SUMMARY

LIC SYSTEM LOAD TEST - BASIC TRACKING

Train:	OV-3
Length:	5400 ft.
Left Lillooet:	1955 K November 4, 1981
Equipment Used:	Units 710 and 717 with head end power. Unit 706 with remote power.
Cabooses:	1870, 1875 and 1872 on rear of train.
Cycle:	Set to 5 seconds.

All ELU spoke up via Mission and reported.

Crossing transponder south of Lillooet in a normal manner until tests started, with the exception of caboose 1870 failed after crossing transponder 135 at mile 148.5 due to dead batteries.

Test 1 (Cycle Set at 5 Seconds)

Time	Mile	
20:47:37	140.7	Disabled Communications Channel and Equipment Deleted
20:52:17	139.2	Restored Communications Channel
20:52:17		Speak Up From 717 - 4:40 Down Time
20:52:25		Speak Up From 710 - 4:46 Down Time
20:53:40		Speak Up From 706 - 5:03 Down Time
20:54:32		Speak Up From 1872 - 6:55 Down Time
20:54:44		Speak Up From 1875 - 7:07 Down Time
20:54:45		Five Transponders Encountered and Reported

FIGURE E-5 (a)

Test 2 (27 Transponders Reported)

20:56:22	Disabled Communications Channel and Equipment Deleted, Mile 138.2
21:11:15	Restored Communications Long Enough to Receive Speak Up - 706 and 1872 Train, Mile 134.6
21:11:15	Speak Up Received From 706, Down Time 15:09
21:11:25	Speak Up Received From 1872, Down Time 15:19, Two Transponders Encountered and Reported
21:11:57	Deleted 706
21:12:09	Deleted 1872
21:37:35	Mile 124.1 Approximately, Communications Restored
21:37:35	Speak Up Received From 710, Mile 124.1, Down Time 42.03
21:37:52	Speak Up Received From 717, Mile 124.1, Down Time 42:03
21:40:30	Speak Up Received From 1872, Mile 123.5, Down Time 28:21
21:45:28	Speak Up Received From 1875, Mile 121.7, Down Time 47:06
21:55:25	Speak Up Received From 706, Mile 119.9, Down Time 43:28

FIGURE E-5 (b)

Test 3 (29 Transponders Reported)

22:16:00	Disabled Communications Channel Did Not Delete, Mile 113
22:24:00	Restored Communications Channel
22:26:13	Speak Up Received From 710 Via Spetch
22:26:16	Speak Up Received From 1875 Via Mission
22:26:41	Speak Up Received From 706 Via Spetch
22:26:59	Speak Up Received From 1872 Via Spetch
22:28:08	Speak Up Received From 717 Via Whistler

Because 1875 spoke up via Mission, polling was sent to Mission and had to go into communications failure and speak up again at 22:41:54 via Whistler. Train at mileage 106.

22:36:00	Mile 108 Approximately, Communications Lost with 710 Via Mission
22:42:14	1875 Speaking Up Via Spetch
22:48:22	710 Speaking Up Via Pemberton Train MB 103.9

FIGURE E-5(c)

Test 4 (17 Transponders Reported)

22:51:13	Disabled the Communications Channel, Train MB 102, No Deletions

Noted that it took from 22:53:13 until 22:54:23 to go through polling list, once Fringer area, Pemberton, and Spetch. DCP responses wait was set internally at approximately 2.08 seconds. The normal setting is 1.04 seconds.

22:24:03	Communications Restored
22:24:03	710 was Talked to From the Polling List
22:24:03	706 Speak Up Via Pemberton
22:24:22	717 was Talked to From the Polling List
22:24:50	1875 was Talked to From the Polling List
22:26:07	1872 was Talked to From the Polling List

Test 5 (6 Transponders Reported)

23:47:02	Disabled All Remote Sites - Cycle Set to 1 Second
23:55:29	Enabled Whistler A Only - Train at Mile 87

Between 23:55:29 and 00:01:02 none of the equipment went into communications failure but, neither the 706 nor 1875 were communicated with.

00:01:04	System Reset - Train at Mile 84.2 Approximately, Cycle Reset to 5 Seconds

FIGURE E-5 (d)

Test 6

01:21:52	Disabled Communications Channel, Train at MB 69.9
01:58:49	Communications Channel Restored

Train at MB 56 and because of tear in paper, the LA-120 sent a control 5 to the DCP. Due to buffer overflow, this crashed the DCP and the system had to be re-started.

Test 7 (7 Transponders Reported)

02:14:03	Disabled Communications Channel, Train at Mile 53 Approximately, Equipment was Not Deleted
02:21:39	Communications Channel Restored, Train at Mile 48 Approximately
02:21:39	717 Speak Up Via Watts
02:21:56	1872 Polled From Whistler
02:22:19	710 Polled From Whistler
02:22:34	706 Polled From Whistler
02:24:13	1875 Polled From Whistler

It was felt that all necessary tests were made and testing was terminated at this time.

FIGURE E-5 (e)

APPENDIX F

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

FULL TRACKING

ACCEPTANCE TEST PLAN

AND SAMPLE RESULTS

BRITISH COLUMBIA RAILWAY

Full Tracking

1. The objective is to evaluate the full train tracking functions and dispatcher assist features with a single HOST/DCP configuration. The system will be shown to be capable of tracking up to twenty LIC equipped units or provisional trains on the subdivision at any one time.

   Performance will be evaluated against previously established standards for an aggregate period of thirty days of error free LIC operation. Error free will be defined as a level of operation whereby the system meets the tracking performance requirements established in the specification. Furthermore, operational hours will only be accrued when system availability at the control office is 91% or more and individual vehicles complete at least 96% of a trip error free.

   Glenayre and Datap will jointly conduct the tests and provide system support during the evaluation period. B.C. Rail will ensure traffic levels such that all criteria can be met within the specified period and will furthermore endeavour to operate LIC equipped engines and cabooses as trains. It will be B.C. Rail's responsibility to gather the generated statistics and to evaluate and document the system's performance.

   The given functions will be independently evaluated, failure of any single function will not be taken as a failure of the overall test phase. The following functions will be evaluated against the criteria given.

2. Transponder Reporting - the following data will be generated for all LIC transponder crossings:

   (a) Data and time of day.

   (b) Unit ID.

   (c) Transponder number.

(d) Location

(e) Time of transponder crossing (+or-30s).

B.C. Rail will transcribe the data into a format compatable to that used for previously obtained results. In addition, they will generate separate records of location and vehicle statistics, pertaining to the transponders and equipped vehicles in use at the time.

The reporting criteria will be based on a series of samples of 10,000 LIC operational crossing reports, a minimum of four such samples being required to satisfy test requirements. For each sample the number of legitimately missed transponders will be determined. This figure will be used in conjunction with the sample size to verify the mean reporting success is in excess of 99.8%. Furthermore, the mean reporting success for all samples will be averaged to prove the overall reporting success is in excess of 99.8% Any deterioration in reporting between samples will be immediately investigated and such corrective actions as is necessary taken.

In the event that the transponder reporting success is found to be less than 99.8%, then the contribution to this reduction of the Digitrac and communication systems will be separately evaluated.

Furthermore, transponder reporting will be compared with the transponder reporting histories obtained from previous tests.

3. Odometer Calibration - statistics will be gathered to verify that the specified calibration procedure is followed for the tracking only mode. The following criteria will be met:

   (a) Speak-up at first detected transponder.

   (b) Infer direction at second transponder.

   (c) Simple calibration at third transponder at least one mile from second.

   (d) Full calibration at next suitable transponder.

(e) Automatic recalibration on detection of greater than a 0.05 mile error at a transponder.

(f) Accumulated odometer error will not exceed 0.1 mile.

B.C. Rail will gather the statistics from the DCP report printer and evaluate the results against those previously obtained.

4. Communications Coverage - the following communication statistics will be generated for each of the units in service:

   (a) Total number of transmissions for trip.

   (b) Total number of responses for trip.

   (c) Total number of speak-ups for trip.

   Furthermore, the results will be compiled and evaluated to give location, vehicle and individual site coverage statistics. B.C. Rail will analyse and compare communications system performance with previously obtained results. Specifically, they will endeavour to pinpoint any areas of poor coverage that could lead to a degradation of system safety. Adequate performance of the communications subsystem is a specific requirement of B.C. Rail.

5. Train Location - data specifying the location of all units being tracked will be maintained for the duration of testing. The location of units or trains will be given to within 0.5M of the actual location in the following manner:

   (a) A train graph will be produced by the DCP, this will provide the unit ID versus mileage for engines at five minute intervals and at CP crossings for cabooses. The results will be compared with previous results and checked against the transponder reports for accuracy.

   This test will be the specific responsibility of Glenayre.

(b) The HOST system will provide the location and ID of all LIC engines on a graphics track diagram display. It will be shown that the train representation arrow is located in the same block as the train that it depicts. Also, the scaled distance of the arrow through this block will be compared with the actual distance travelled into the block. The arrow will always show the last known direction of travel.

All possible sections of track will be tested for location, using the V-10 vehicle, if necessary, to perform moves over rarely used trackage.

This test will be the specific responsibility of Datap.

6. Dispatcher Assist Functions - the following HOST system dispatcher assist features will be operationally evaluated by B.C. Railway during the test period:

   (a) Train Sheet Manipulation - train sheets will be generated for all LIC equipped trains operating over the subdivision.

   (b) Reports and Logs - all possible reports and logs will be exercised during the test period.

   (c) Dispatcher Shift Change - the dispatcher transfer function will be verified.

   (d) The graphics display will be evaluated in accordance with the specification for overall operating suitability.

   B.C. Railway will fully document and comment on their findings with respect to the dispatcher assist functions.

7. System Loading - the system will be demonstrated as meeting the full functional requirements of tracking 13 LIC equipped trains. The loading on the system will be increased by severing and reinstating firstly the communications link and then the DCP and communications link simultaneously.

```
1983 02 23 12:14  23  N01    1487 F0 00
1983 02 23 12:14  21  N01    BC31L 039 10H 000 148.79 0269 MM A
1983 02 23 12:14  02  N01    BC31L 040 23B49BH 000000H 148.82 MM A
1983 02 23 12:14  23  N01    1487 30 00
1983 02 23 12:14  10  N01    BC11E 000 00H 000 000.00 0235 MM A
1983 02 23 12:15  24  N01    1441 F0 00
1983 02 23 12:15  21  N01    BC11E 000 00H 002 000.00 0269 MM A
1983 02 23 12:15  20  N01    BC11E 148.75 00077 00037        048.00 %  01427 00980 069.00 %
1983 02 23 12:16  23  N01    1498 F0 00
1983 02 23 12:16  21  N01    BC11E 000 00H 000 000.00 0182 MM A
1983 02 23 12:16  23  N01    1498 F0 00
1983 02 23 12:16  21  N01    BC31L 039 10H 001 149.86 0182 MM A
1983 02 23 12:16  26  N01    1498 F0 00
1983 02 23 12:16  23  N01    1498 F0 00
1983 02 23 12:16  21  N01    BC31L 037 10H 001 149.92 0051 MM A
1983 02 23 12:16  02  N01    BC31L 034 22B49BH 000000H 150.01 MM A
1983 02 23 12:16  24  N01    1487 30 00
1983 02 23 12:16  21  N01    BC11E 000 00H 000 000.00 0051 MM A
1983 02 23 12:17  20  N01    BC31L 150.53 00061 00060        099.00 %  01400 01123 080.00 %
1983 02 23 12:20  23  N01    1520 F0 00
1983 02 23 12:20  21  N01    BC31L 029 10H 000 152.07 0148 MM A
1983 02 23 12:20  26  N01    1520 F0 00
1983 02 23 12:20  23  N01    1520 F0 00
1983 02 23 12:20  21  N01    BC31L 029 10H 001 152.08 0229 MM A
1983 02 23 12:20  02  N01    BC31L 030 21B49BH 000000H 152.14 MM A
1983 02 23 12:20  02  N01    BC31L 030 21B4DBH 000000H 152.14 MM A
1983 02 23 12:20  14  N01    BC31L 030 +006 000 119 152.14 0201 00004 00007 00006
1983 02 23 12:21  23  N01    1520 F0 00
1983 02 23 12:21  21  N01    BC11E 000 00H 000 000.00 0148 MM A
1983 02 23 12:21  24  N01    1498 F0 00
1983 02 23 12:21  21  N01    BC11E 000 00H 000 000.00 0229 MM A
1983 02 23 12:21  20  N01    BC11E 152.02 00050 00035        070.00 %  01477 01015 069.00 %
1983 02 23 12:22  02  N01    BC31L 029 2164DBH 000000H 152.84 MM A
1983 02 23 12:22  25  N01    1565 F0 00
1983 02 23 12:22  02  N01    BC31L 030 2274DBH 000000H 152.88 MM A
1983 02 23 12:27  20  N01    BC31L 155.52 00073 00063        087.00 %  01473 01186 081.00 %
1983 02 23 12:27  23  N01    1555 F0 00
1983 02 23 12:27  21  N01    BC31L 043 50H 000 155.52 0201 MM A
```

FIGURE F-1 EXAMPLE OF DCP PRINTOUT

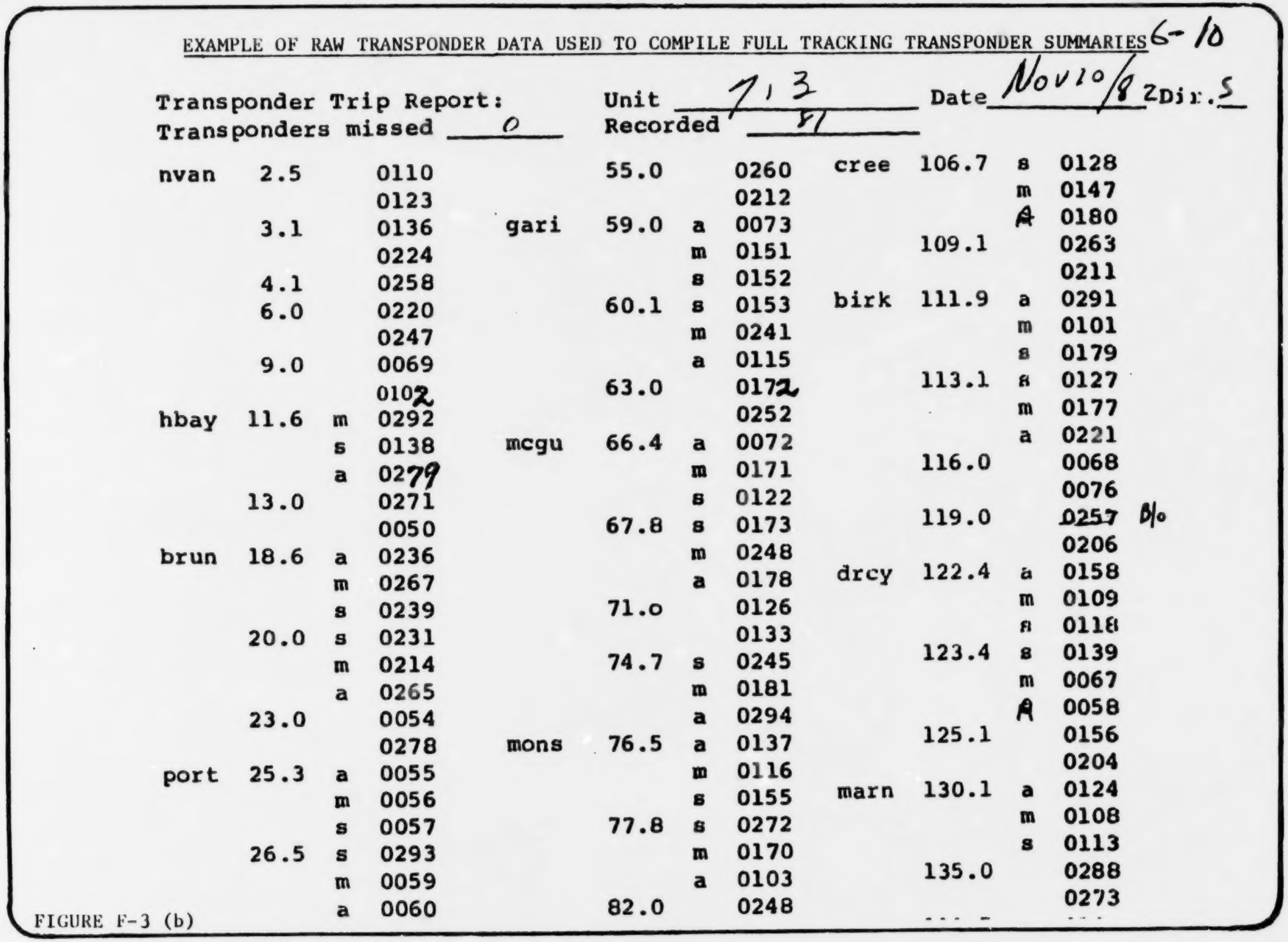
```
11:56:14  SFK ACTION ISSUE  CD  ACCEPT  N01                      1520       11:56:07
11:56:18  EVENT TRANS CROSSED      0164       BC31 140.0 32 N               11:56:16
11:56:21  EVENT TRANS CROSSED      0256       BC31 140.0 34 N               11:56:18
11:56:32  EVENT TRANS CROSSED      0164       BC11   0.0  0 N               11:56:15
11:56:45  EVENT TRANS CROSSED      0256       BC11   0.0  0 N               11:56:13
11:56:50  SFK ACTION ISSUE  CD  ACCEPT  N01                      1555       11:56:41
11:57:16  USER ACTION   DISPLAY REQUEST  ACCEPT  N01
11:58:10  USER ACTION   T.S. DATA ENTRY  ACCEPT  TEST1
11:59:11  USER ACTION   T.S. DATA ENTRY  ACCEPT  TEST1
12:00:23  SFK ACTION ISSUE  ACK ACCEPT  TEST1                               12:00:14
12:00:48  ALERT  ELU FAIL   CAB DISPLAY      V10    0.0  0 TEST1
12:01:56  USER ACTION   REPORT REQUEST   ACCEPT  TEST1
12:02:24  SFK ACTION ISSUE  ACK ACCEPT  TEST1                               12:02:18
12:02:41  SFK ACTION ISSUE  DIS ACCEPT  TEST1                               12:02:38
12:04:01  SFK ACTION ISSUE  ACK REJECT  TEST1                               12:03:55
12:05:29  SFK ACTION ISSUE  ACK ACCEPT  TEST1                               12:05:24
12:05:49  SFK ACTION ISSUE  DIS ACCEPT  TEST1                               12:05:43
12:06:08  SFK ACTION ISSUE  ACK REJECT  TEST1                               12:06:01
12:06:32  EVENT TRANS CROSSED      0046       BC31 144.2 32 N               12:06:29
12:06:41  EVENT TRANS CROSSED      0046       BC11   0.0  0 N               12:06:23
12:07:15  SFK ACTION CANCEL DIS ACCEPT  TEST1                               12:07:07
12:07:44  SFK ACTION ISSUE  ACK ACCEPT  TEST1                               12:07:37
12:08:18  SFK ACTION CANCEL ACK REJECT  TEST1                               12:08:18
12:08:59  SFK ACTION ISSUE  DIS ACCEPT  TEST1                               12:08:55
12:09:49  SFK ACTION CANCEL DIS ACCEPT  TEST1                               12:09:41
12:10:11  SFK ACTION ISSUE  ACK ACCEPT  TEST1                               12:10:02
12:10:42  USER ACTION   DISPLAY REQUEST  ACCEPT  N01
12:11:48  SFK ACTION ISSUE  ACK REJECT  N01                                 12:11:30
12:12:04  SFK ACTION ISSUE  ACK ACCEPT  N01                                 12:12:01
12:12:22  USER ACTION   DISPLAY REQUEST  ACCEPT  N01
12:13:38  USER ACTION   DISPLAY REQUEST  ACCEPT
12:14:41  EVENT TRANS CROSSED      0235       BC31 148.7 36 N               12:14:39
12:14:44  ABNORMAL  VIOLATION HIGH SPEED      BC31 148.8 91 N01          91 12:14:42
12:14:45  EVENT TRANS CROSSED      0269       BC31 148.8 39 N               12:14:42
12:14:53  EVENT TRANS CROSSED      0235       BC11   0.0  0 N               12:14:51
12:15:20  ABNORMAL  VIOLATION HIGH SPEED      BC11   0.0 91 N01          91 12:14:48
12:15:21  EVENT TRANS CROSSED      0269       BC11   0.0  0 N               12:14:48
12:15:40  SFK ACTION ISSUE  ALM ACCEPT  N01                      1487       12:15:40
12:15:51  SFK ACTION ISSUE  ALM ACCEPT  N01                      1487       12:15:51
12:16:08  USER ACTION   DISPLAY REQUEST  ACCEPT  N01
12:16:38  EVENT TRANS CROSSED      0182       BC11   0.0  0 N               12:16:21
12:16:41  EVENT TRANS CROSSED      0182       BC31 149.9 39 N               12:16:24
12:16:44  EVENT TRANS CROSSED      0051       BC31 149.9 37 N               12:16:27
12:16:50  EVENT TRANS CROSSED      0051       BC11   0.0  0 N               12:16:48
```

FIGURE F-2 EXAMPLE OF HOST PRINTOUT

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES 6-9

```
Transponder Trip Report:             Unit     720          Date Nov 9      Dir N
Transponders missed    2             Recorded  111

nvan   2.5      0110               55.0     0260   cree  106.7  s  0128
                0123                        0212                m  0147
       3.1      0136   gari        59.0  a  0073                A  0180
                0224                     m  0151         109.1     0263
       4.1      0258                     s  0152                   0211
       6.0      0220               60.1  s  0153   birk  111.9  a  0291
                0247                     m  0241                m  0101
       9.0      0069                     a  0115                s  0179
                0102               63.0     0172         113.1  s  0127
hbay  11.6  m   0292                        0252                m  0177
            s   0138   mcgu        66.4  a  0072                a  0221
            a   0279                     m  0171         116.0     0068
      13.0      0271                     s  0122                   0076
                0050               67.8  s  0173         119.0     0257 B/O
brun  18.6  a   0236                     m  0248                   0206
            m   0267                     a  0178   drcy  122.4  a  0158
            s   0239               71.o     0126                m  0109
      20.0  s   0231                        0133                s  0118
            m   0214               74.7  s  0245         123.4  s  0139
            a   0265                     m  0181                m  0067
      23.0      0054                     a  0294                A  0058
                0278   mons        76.5  a  0137         125.1     0156
port  25.3  a   0055                     m  0116                   0204
            m   0056                     s  0155   marn  130.1  a  0124
            s   0057               77.8  s  0272                m  0108
      26.5  s   0293                     m  0170                s  0113
            m   0059                     a  0103         135.0     0288
            a   0060               82.0     0248                   0273
```

FIGURE F-3 (a)



EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES 6-10

Transponder Trip Report: Unit 7,3 Date Nov10/82 Dir.: S

Transponders missed 0 Recorded 81

nvan	2.5		0110		55.0		0260	cree	106.7	s	0128
			0123				0212			m	0147
	3.1		0136	gari	59.0	a	0073			A	0180
			0224			m	0151		109.1		0263
	4.1		0258			s	0152				0211
	6.0		0220		60.1	s	0153	birk	111.9	a	0291
			0247			m	0241			m	0101
	9.0		0069			a	0115			s	0179
			0102		63.0		0172		113.1	s	0127
hbay	11.6	m	0292				0252			m	0177
		s	0138	mcgu	66.4	a	0072			a	0221
		a	0279			m	0171		116.0		0068
	13.0		0271			s	0122				0076
			0050		67.8	s	0173		119.0		~~0257~~ B/o
brun	18.6	a	0236			m	0248				0206
		m	0267			a	0178	drcy	122.4	a	0158
		s	0239		71.0		0126			m	0109
	20.0	s	0231				0133			s	0118
		m	0214		74.7	s	0245		123.4	s	0139
		a	0265			m	0181			m	0067
	23.0		0054			a	0294			A	0058
			0278	mons	76.5	a	0137		125.1		0156
port	25.3	a	0055			m	0116				0204
		m	0056			s	0155	marn	130.1	a	0124
		s	0057		77.8	s	0272			m	0108
	26.5	s	0293			m	0170			s	0113
		m	0059			a	0103		135.0		0288
		a	0060		82.0		0248				0273

FIGURE F-3 (b)

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES 6-11

Transponder Trip Report: **Unit** 720 **Date** Nov 21/81 **Dir.** S

Transponders missed 0 **Recorded** 111

nvan	2.5		0110
			0123
	3.1		0136
			0224
	4.1		0258
	6.0		0220
			0247
	9.0		0069
			0102
hbay	11.6	m	0292
		s	0138
		a	0279
	13.0		0271
			0050
brun	18.6	a	0236
		m	0267
		s	0239
	20.0	s	0231
		m	0214
		a	0265
	23.0		0054
			0278
port	25.3	a	0055
		m	0056
		s	0057
	26.5	s	0293
		m	0059
		a	0060

	55.0		0260
			0212
gari	59.0	a	0073
		m	0151
		s	0152
	60.1	s	0153
		m	0241
		a	0115
	63.0		0172
			0252
mcgu	66.4	a	0072
		m	0171
		s	0122
	67.8	s	0173
		m	0248
		a	0178
	71.0		0126
			0133
	74.7	s	0245
		m	0181
		a	0294
mons	76.5	a	0137
		m	0116
		s	0155
	77.8	s	0272
		m	0170
		a	0103
	82.0		0248

cree	106.7	s	0128
		m	0147
		A	0180
	109.1		0263
			0211
birk	111.9	a	0291
		m	0101
		s	0179
	113.1	s	0127
		m	0177
		a	0221
	116.0		0068
			0076
	119.0		~~0227~~ 0/0
			0206
drcy	122.4	a	0158
		m	0109
		s	0118
	123.4	s	0139
		m	0067
		A	0058
	125.1		0156
			0204
marn	130.1	a	0124
		m	0108
		s	0113
	135.0		0288
			0273

FIGURE F-3 (c)

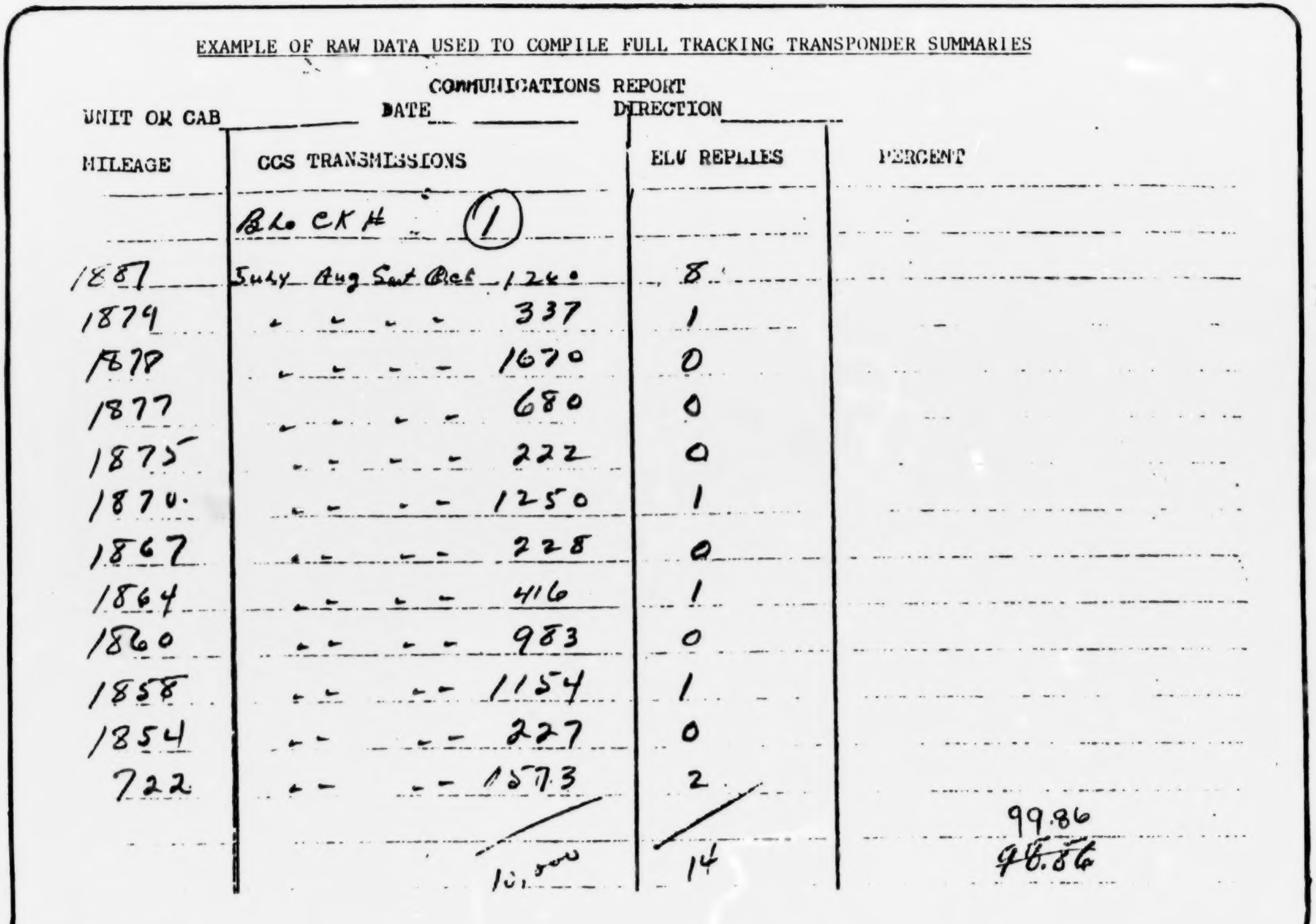
EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES 6-12

Transponder Trip Report: Unit 717 Date Nov 21/82 Dir. S

Transponders missed 0 Recorded 111

```
nvan    2.5     0110            55.0    0260    cree  106.7  s  0128
                0123                    0212                 m  0147
        3.1     0136    gari    59.0 a  0073                 A  0180
                0224                 m  0151          109.1     0263
        4.1     0258                 s  0152                    0211
        6.0     0220            60.1 s  0153    birk  111.9  a  0291
                0247                 m  0241                 m  0101
        9.0     0069                 a  0115                 s  0179
                0102            63.0    0172          113.1  s  0127
hbay   11.6  m  0292                    0252                 m  0177
             s  0138    mcgu    66.4 a  0072                 a  0221
             a  0277                 m  0171          116.0     0068
       13.0     0271                 s  0122                    0076
                0050            67.8 s  0173          119.0     0257 Bo
brun   18.6  a  0236                 m  0248                    0206
             m  0267                 a  0178    drcy  122.4  a  0158
             s  0239            71.o    0126                 m  0109
       20.0  s  0231                    0133                 s  0118
             m  0214            74.7 s  0245          123.4  s  0139
             a  0265                 m  0181                 m  0067
       23.0     0054                 a  0294                 A  0058
                0278    mons    76.5 a  0137          125.1     0156
port   25.3  a  0055                 m  0116                    0204
             m  0056                 s  0155    marn  130.1  a  0124
             s  0057            77.8 s  0272                 m  0108
       26.5  s  0293                 m  0170                 s  0113
             m  0059                 a  0103          135.0     0288
             a  0060            82.0    0248                    0273
```

FIGURE F-3 (d)



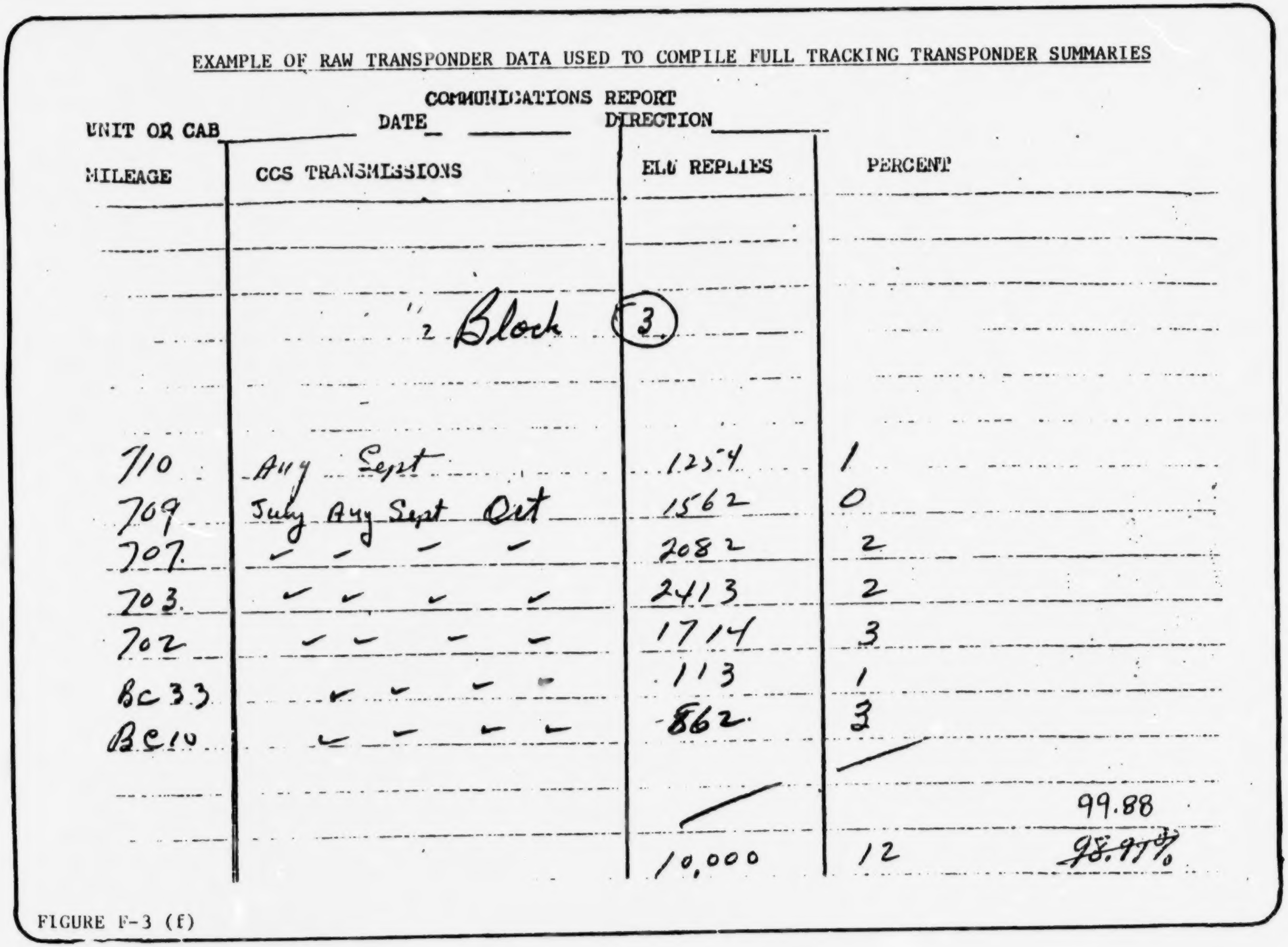
EXAMPLE OF RAW DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES

COMMUNICATIONS REPORT

UNIT OR CAB ______ DATE ______ DIRECTION ______

MILEAGE	CCS TRANSMISSIONS	ELU REPLIES	PERCENT
	Block # ①		
1887	July Aug Sept Oct 1240	8	
1879	- - - - 337	1	
1878	- - - - 1670	0	
1877	- - - - 680	0	
1875	- - - - 222	0	
1870	- - - - 1250	1	
1867	- - - - 228	0	
1864	- - - - 416	1	
1860	- - - - 983	0	
1858	- - - - 1154	1	
1854	- - - - 227	0	
722	- - - - 1573	2	
			99.86
	10,000	14	~~98.86~~

FIGURE F-3 (e)



EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES

COMMUNICATIONS REPORT

UNIT OR CAB________ DATE________ DIRECTION________

MILEAGE	CCS TRANSMISSIONS	ELU REPLIES	PERCENT	
	½ Block	③		
710	Aug Sept	1254	1	
709	July Aug Sept Oct	1562	0	
707	✓ ✓ ✓ ✓	2082	2	
703	✓ ✓ ✓ ✓	2413	2	
702	✓ ✓ ✓ ✓	1714	3	
Bc33	✓ ✓ ✓ ✓	113	1	
Bc10	✓ ✓ ✓ ✓	862	3	
				99.88
		10,000	12	~~98.99%~~

FIGURE F-3 (f)

EXAMPLE OF RAW TRANSPONDER DATA USED TO COMPILE FULL TRACKING TRANSPONDER SUMMARIES
1982

Unit or Cab ________

DATE	Number Encountered	Number Reported	Number Unreported	Percentage
	BLOCK	# ④		
713	NOV 1982	544	0	
715	✓	969	0	
716	✓	1338	6	
717	✓	1161	1	
719	✓	474	1	
720	✓	887	2	
721	✓	1071	4	
722	✓	1301	2	
1854	✓	333	0	
1855	✓	111	0	
1858	✓	777	0	
1860	✓	332	0	
1864	✓	111	0	
1865	✓	591	0	
		10,000	16	99.84%

FIGURE F-3 (g)

Test #1

Units 713 and 7803 ex Lillooet 0140 January 30th to North Vancouver.

Transponder Location	Transponder Number	Unit 713 Reading	Unit 703 Reading	Time At Siding
Seton				30 Mins.
A	256	+.06	+.03	Wait,
M	164	+.05	+.03	Meet
M	150	+.06	+.03	
A	132	Re Cal	+.03	
Mons				30 Mins.
A	103	.00	+.09	Switchng
M	170	.00	+.10	
M	116	.00	+.10	
A	137	.00	Re Cal	
McGuire				50 Mins.
A	178	+.02	+.01	Wait,
M	284	+.02	.00	Meet
M	171	+.04	-.10	
A	72	+.04	-.14	
Squamish				2 Hours,
A	282	+.01	.00	50 Mins.
M	230	+.01	+.44	Switchng
M	215	+.04	+.31	
A	62	+.04	Re Cal	

Copies of calibration performance attached.

FIGURE F-4 (a)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST – DATE Jan 30/83 UNIT 703-S

Old Software

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
2.53	110	2.48							
2.54	123	2.49							
3.09	136	3.05							
3.10	224	3.06							
6.03	220	5.99							
6.04	247	6.00							
9.04	69	9.03							
9.05	258	9.04							
11.63	138/292	11.62							
11.68	279	11.67							
13.02	271								
13.06	50	13.06							
18.67	236	18.61	14	101	15.98	9	38	No	
18.72	239/267								
20.04	231/214								
20.09	265								
23.07	54								
23.08	278								
25.34	55								
25.39	57/56								
26.26	293/59								
26.30	60								
30.17	297								
30.18	249								
34.10	207								
34.11	205								
38.06	222								

FIGURE F-4 (b)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 30/65 UNIT 713-2

CATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255								
103.12	144								
105.61	202								
105.66	106/146								
106.66	128/147								
106.71	180								
109.11	263								
109.12	211	109.12							
111.88	291	111.80	14	211	111.76	3	8	8	
111.95	101/179								
113.09	127/177								
113.14	221								
116.09	68								
116.10	76								
119.08	216								
119.09	206								
122.43	158								
122.48	109/118								
123.41	67/139								
123.46	58								
125.11	156	125.10							
125.12	204	125.11							
130.26	124	130.20	14	204	130.10	2	6	6	
130.31	108	130.26							
135.06	288	135.03							
135.07	273	135.05							
138.74	132	138.74							
138.79	/150	138.73	14	132	139.67	1	6	6	→ STOPPED [illegible]

FIGURE F-4 (c)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 20/83 UNIT 713-S (old software)

-2 -1 0 +1 +

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRS ERR	ODOMETER IN TENTHS OF A MILE
2.53	110	2.47							
2.54	123	2.48							
3.09	136	3.03							
3.10	224	3.04							
6.03	220	5.99							
6.04	247	6.00							
9.04	69	9.03							
9.05	258	9.05							
11.63	138/292	11.64							
11.68	279	11.68							
13.02	271	12.93	14	279	12.24	10	10	7	
13.06	50	12.99							
18.67	236								
18.72	239/267								
20.04	231/214								
20.09	265								
23.07	54								
23.08	278	23.08							
25.34	55	25.29	14	278	24.68	9	10	6	
25.39	57/56	25.33							
26.26	293/59								
26.30	60								
30.17	297								
30.18	249								
34.10	207								
34.11	205	34.11							
38.06	222	38.01	14	205	3783	8	10	6	
38.07	281	38.01							

FIGURE F-4 (d)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 30/83 UNIT 703-2

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIN CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
03.11	255								
03.12	144								
05.61	202								
05.66	106/146								
06.66	128/147								
06.71	180								
09.11	263								
09.12	211	109.12							
11.88	291	111.81	14	211	111.83	2	13	8	
11.95	101/	111.87							
13.09	127/177								
13.14	221								
16.09	68								
16.10	76								
19.08	216								
19.09	206								
22.43	158								
22.48	109/118								
23.41	67/139								
23.46	58								
25.11	156								
25.12	204								
30.26	124	130.26							
30.31	108	130.42	14	124	135.10	1	13	13	
35.06	288	135.19							
35.07	273	135.20							
38.74	132	138.71							
38.79	168/150	138.76			MEET				
39.87	111/164	139.24							

FIGURE F-4 (e)

Test #2

Unit 713 left North Vancouver January 31, 1983.

Transponder Location	Transponder Number	Unit 713 Reading	Time at Siding & Work Performed
Squamish			1 Hour, 10 Mins.
A	62	+.07	Squamish Switchng
M	215	+.07	
M	238	+.07	
A	282	Re Cal	
Garibaldi			12 Mins. Meeting
A	73	+.03	
S	152	+.03	
S	153	+.04	
A	115	+.05	

Note: Transponder #172 +.09 Mileage 62.99, slow speed acct. re-line north switch.

Copies of calibration performance attached.

FIGURE F-4 (f)

BRITISH COLUMBIA RAILWAY

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 713- (old Software)

LOCATION	XPNDR NUMBER	ODOMETER READING	CL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	ODOMETER IN TENTHS OF A MILE -2 -1 0 +1
2.53	110	.21			(a347)				
2.54	123	.20							
3.09	136	-.35							
3.10	224	-.36							
6.03	220	-3.31							
6.04	247	-3.32							
9.04	69								
9.05	258								
11.63	138/292								
11.68	279								
13.02	271	-10.35							
13.06	50	-10.41	14	236	-12.28	12	252	252	
18.67	236	18.67							
18.72	239/267								
20.04	231/214								
20.09	265								
23.07	54								
23.08	278								
25.34	55								
25.39	57/56								
26.26	293/59								
26.30	60	26.37	14	297	27.91	13	252	7	
30.17	297	30.17							
30.18	249								
34.10	207								
34.11	205								
38.06	222								
38.07	281								

FIGURE F-4 (g)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 713

(old software)

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255	103.11							
103.12	144								
105.61	202								
105.66	106/146								
106.66	128/147								
106.71	180								
109.11	263								
109.12	211								
111.88	291								
111.95	101/179	112.01							
113.09	127/177	113.16	10	107	112.57	20	252	6	
113.14	221	113.21							
116.09	68	116.17							[illegible]
116.10	76	116.18		[illegible]	.10				[illegible]
119.08	216	119.18							
119.09	206	119.19	14	158	121.27	21	252	8	
122.43	158	122.43							
122.48	109/118								
123.41	67/139								
123.46	58								
125.11	156								
125.12	204								
130.26	124								
130.31	108/113								
135.06	288	135.12							
135.07	273	135.13	14	132	135.38	22	252	6	
138.74	132	138.74							
138.79	168/150								

FIGURE F-4 (h)

Test #3

Unit 712 and 707 ex Lillooet 0100 January 31st to North Vancouver.

Transponder Location	Transponder Number	Unit 712 Reading	Unit 707 Reading	Time at Siding
Darcy				20 Mins.
A	058	+.02	+.04	Wait,
M	139	+.02	+.04	Meet
M	118	+.02	+.04	
A	158	+.02	+.04	
Mons				15 Mins.
A	103	Cal	.00	Switchng
M	170	.00	-.01	
M	116	.00	+.01	
A	137	.00	+.01	
Garibaldi				20 Mins.
A	115	-.04	-.01	Wait,
M	241	-.01	.00	Meet
M	151	-.01	.00	
A	073	-.01	.00	
Squamish				50 Mins.
A	282	.00	.00	Switchng
M	230	-.01	-.01	
M	061	+.04	-.04	
A	062	+.03	-.04	

Copies of calibration performance attached.

FIGURE F-4 (i)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 707 - S

(Cold [illegible]

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	−2 −1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255								
103.12	144								
105.61	202								
105.66	106/146								
106.66	128/147								
106.71	180								
109.11	263								
109.12	211	109.12							
111.88	291	111.94	14	211	109.94	1	6	6	
111.95	101/179								
113.09	127/177								
113.14	221								
116.09	68								
116.10	76								
119.08	216								
119.09	206	119.14							
122.43	158	122.47							
122.48	118	122.52							
123.41	139	123.45							
123.46	58	123.50							
125.11	156	125.14							
125.12	204	125.15							
130.26	124								
130.31	108/113								
135.06	288								
135.07	273								
138.74	132	138.89	12	273	139.04	0	0	0	
138.79	150	138.94							
139 87	111/164								

FIGURE F-4 (j)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

LIC CALIBRATION TEST DATE JAN 31/83 UNIT 712-S

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255								
103.12	144								
105.61	202								
105.66	106/146								
106.66	128/147								
106.71	180								
109.11	263								
109.12	211								
111.88	291								
111.95	101/179								
113.09	127/177								
113.14	221								
116.09	68								
116.10	76								
119.08	216								
119.09	206	119.10							
122.43	158	122.45							
122.48	118	122.50							
123.41	139	123.43							
123.46	58	123.48							
125.11	156	125.12							
125.12	204								
130.26	124								
130.31	108/113								
135.06	288								
135.07	273								
138.74	132								
138.79	168/150								
139.87	111/164								
139.92	256								

FIGURE F-4 (k)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 701 -

Cold Soak

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
2.53	110	2.55'							
2.54	123								
3.09	136	3.11							
3.10	224								
6.03	220								
6.04	247								
9.04	69								
9.05	258								
11.63	138/292								
11.68	279								
13.02	271								
13.06	50								
18.67	236								
18.72	239/267								
20.04	231/214								
20.09	265								
23.07	54								
23.08	278	23.08							
25.34	55	25.40	14	278	24.82	5	11	6	
25.39	57/56	25.44							
26.26	293/59								
26.30	60								
30.17	297								
30.18	249								
34.10	207								
34.11	205								
38.06	222	38.09							
38.07	281	38.10							

FIGURE F-4 (1)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 712-S

(Cold Software

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	ODOMETER IN TENTHS OF A MILE -2 -1 0 +1
2.53	110	2.47							
2.54	123								
3.09	136								
3.10	224								
6.03	220								
6.04	247								
9.04	69								
9.05	258								
11.63	138/292								
11.68	279								
13.02	271								
13.06	50								
18.67	236								
18.72	239/267								
20.04	231/214								
20.09	265								
23.07	54								
23.08	278								
25.34	55								
25.39	57/56								
26.26	293/59								
26.30	60								
30.17	297								
30.18	249	30.18							
34.10	207	34.04	14	249	33.69	3	11	6	
34.11	205								
38.06	222	38.01							
38.07	281	38.02							
39.16	62	39.13							

FIGURE F-4 (m)

Test #4

Units 707 and 712 left North Vancouver 2200 January 31, 1983.

Transponder Location	Transponder Number	Unit 707 Reading	Unit 712 Reading	Time at Siding
Creekside				12 Mins.
A	202	-.05	-.05	Waiting
S	106	-.04	-.04	Meet at
S	128	-.05	-.05	Creekside
A	180	-.05	-.05	

Copies of calibration performance attached.

FIGURE F-4 (n)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST DATE JAN 31' 83 UNIT 712

ODOMETER IN TENTHS OF A

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2	-1	0	+1
2.53	110	.00										
2.54	123	.00										
3.09	136	.00										
3.10	224	.00										
6.03	220	.00										
6.04	247	.00										
9.04	69	.00										
9.05	258	.00										
11.63	292	.00										
11.68	279	.00										
13.02	271	.00										
13.06	50	.00										
18.67	236	.00										
18.72	267	.00										
20.04	214	.00										
20.09	265	.00										
23.07	54	.00										
23.08	278	.00										
25.34	55	.00										
25.39	56	.00										
26.26	293/59	.00										
26.30	60	.00										
30.17	297	.00										
30.18	249	.00										
34.10	207	.06										
34.11	205	.00	14	222	34.11	4	11	6				
38.06	222	38.06										
38.07	281	38.06	13	213	38.22	4	11	6				
39.16	62	39.15										

FIGURE F-4 (o)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan-31-82 UNIT 712

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255								
103.12	144								
105.61	202	105.56	-.5		51C				
105.66	106/~~150~~	105.62	-.04						
106.66	128/~~147~~	106.61	-.5	—	N1C				
106.71	180	106.66	-.5						
109.11	263	109.05	-.6						
109.12	211	109 06	14	291	109.45	8	11	6	
111.88	291	111.88.							
111.95	101/179								
113.09	127/177								
113.14	221								
116.09	68								
116.10	76								
119.08	216								
119.09	206								
122.43	158								
122.48	109/118								
123.41	67/139								
123.46	58								
125.11	156	125.05							
125.12	204	125.06	14	12+	125.87	9	11	6	
130.26	124	130.76							
130.31	108/113								
135.06	288								
135.07	273								
138.74	132								
138.79	168/150								
139.87	111/164								

FIGURE F-4 (p)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 707-15

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES ERR	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
2.53	110	2.56							
2.54	123	2.57							
3.09	136	3.12							
3.10	224	3.13							
6.03	220	6.05							
6.04	247	6.06							
9.04	69	9.07							
9.05	258								
11.63	~~138~~/292	11.64							
11.68	279	11.69							
13.02	271	13.02							
13.06	50	13.07							
18.67	236	18.66							
18.72	~~239~~/267	18.71							
20.04	~~231~~/214	20.03							
20.09	265	20.08							
23.07	54	23.05							
23.08	278	23.07							
25.34	55	25.30							
25.39	57/56	25.35							
26.26	~~293~~/59	26.22							
26.30	60	26.27							
30.17	297	30.11							
30.18	249	30.12	14	207	30.33	6	11	6	
34.10	207	34.10							
34.11	205	34.10							
38.06	222	38.04							
38.07	281	38.05							

FIGURE F-4 (q)

EXAMPLE OF RAW ODOMETER DATA USED TO COMPILE FULL TRACKING CALIBRATION TESTS

L.I.C. CALIBRATION TEST - DATE Jan 31/83 UNIT 707

LOCATION	XPNDR NUMBER	ODOMETER READING	CAL #	AT XPNDR	MILEAGE	SIM CALS	MAX ERR	PRES PER	-2 -1 0 +1 ODOMETER IN TENTHS OF A MILE
103.11	255								
103.12	144								
105.61	202	105.56	-.5						
105.66	106/~~146~~	105.62	.4						
106.66	128/~~127~~	106.61	.5						
106.71	180	106.66	.5						
109.11	263	109.06	.5						
109.12	211	109.06	14	291	110.36	8	11	6	
111.88	291	111.88							
111.95	101/179								
113.09	127/177								
113.14	221								
116.09	68								
116.10	76								
119.08	216								
119.09	206								
122.43	158								
122.48	109/118								
123.41	67/139								
123.46	58								
125.11	156								
125.12	204								
130.26	124	130.19							
130.31	108/~~113~~	130.24	14	288	130.33	9	11	7	
135.06	288	135.06							
135.07	273								
138.74	132								
138.79	168/150								

FIGURE F-4 (r)

LIC CALIBRATION TEST

Units 712, 713 and as comparison, units 703 and 707 have been tested for both slow speeds and switching for calibration errors.

It has been concluded that in both cases, the error is inconsistent.

On Meets:

Unit 712: Was stopped at 3 locations.
2 locations had no error.
1 location had an error of +.02.

Unit 713: Was stopped at 2 locations.
1 location had no error.
1 location had an error of +.02.

Unit 703: Was stopped at 3 locations.
1 location had no error.
1 location had an error of -.14.
1 location had an error of +.02.

Unit 707: Was stopped at 3 locations.
2 locations had no error.
1 location had an error of +.01.

On Switching:

Unit 712: Switched at 2 locations.
1 location had no error.
1 location had an error of -.01 to +.04.

Unit 713: Switched at 3 locations.
2 locations no error.
1 location had an error of +.03.

Unit 703: Switched at 2 locations.
1 location had an error of -.01.
1 location had an error of +.44.

Unit 707: Switched at 2 locations.
1 location had an error of -.01 to +.01.
1 location had an error of -.04.

FIGURE F-4 (s)

L.I.C CALIBRATION TEST

DATE JAN 30/83 UNIT NO 703 DIRECTION S

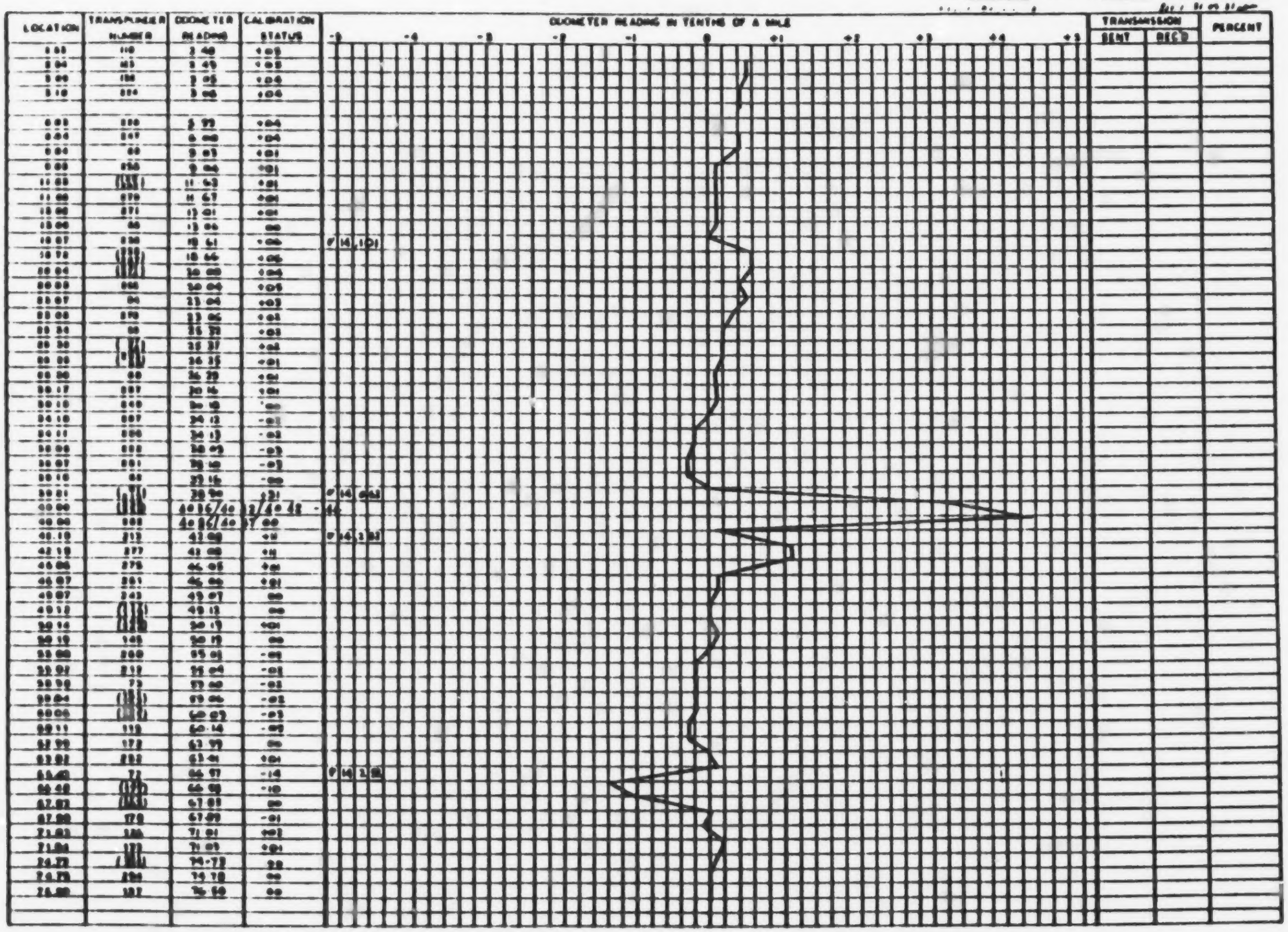


FIGURE F-4 (t)

L.I.C. CALIBRATION TEST

DATE JAN 30/81 UNIT NO. 703 DIRECTION 5

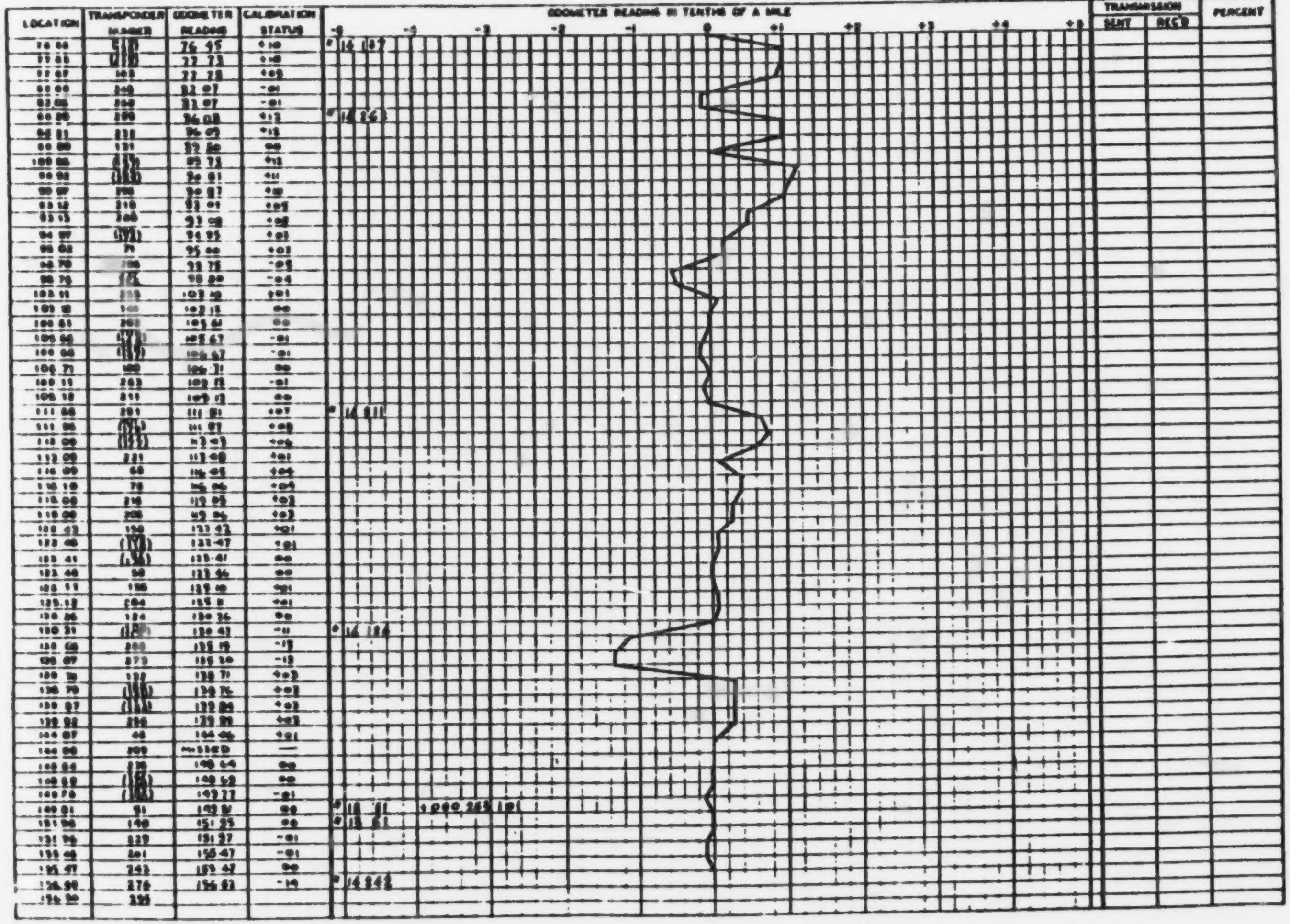


FIGURE F-4 (u)

L.I.C. CALIBRATION TEST

DATE JAN 31/83 UNIT NO 712 DIRECTION S

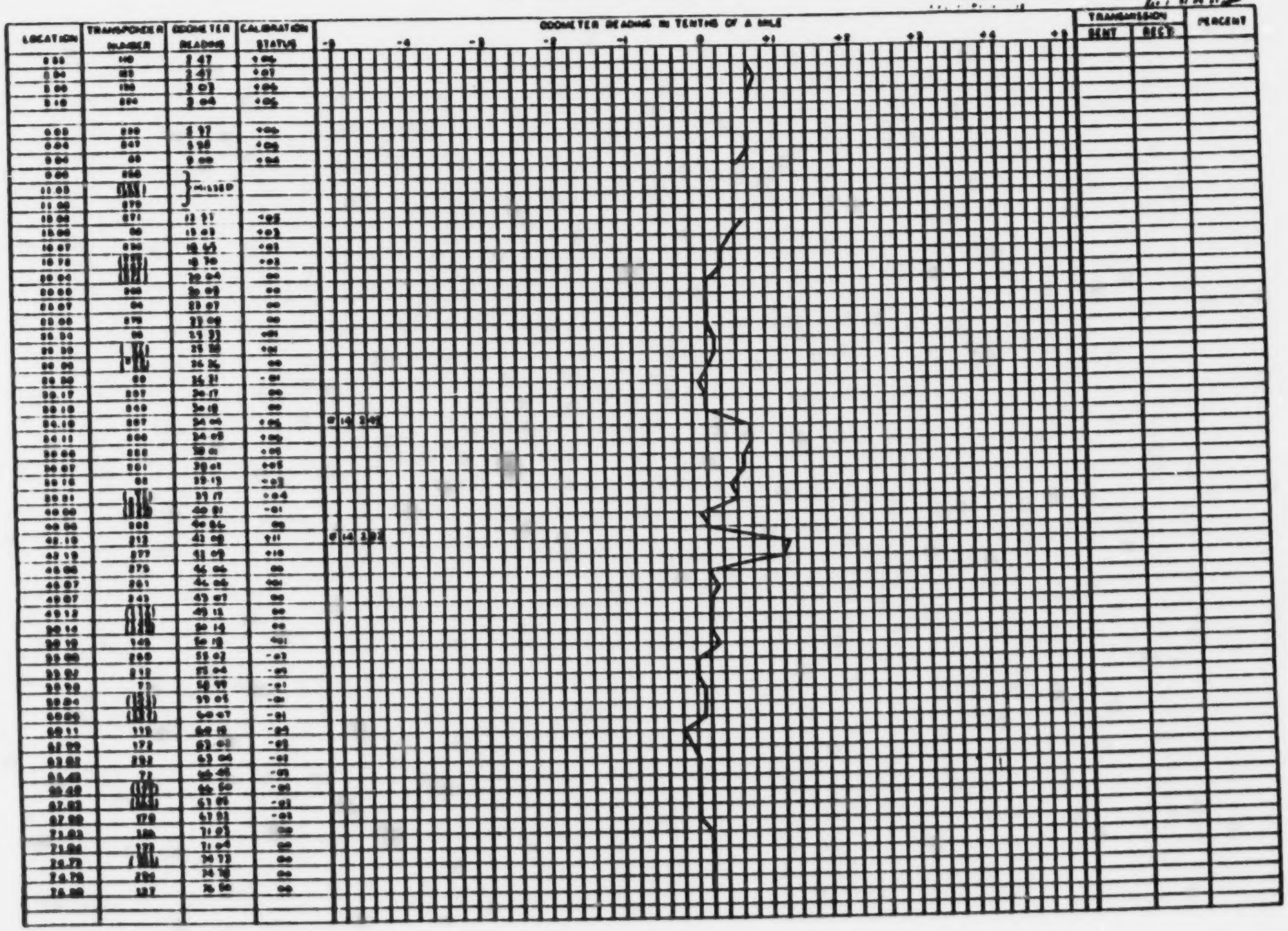
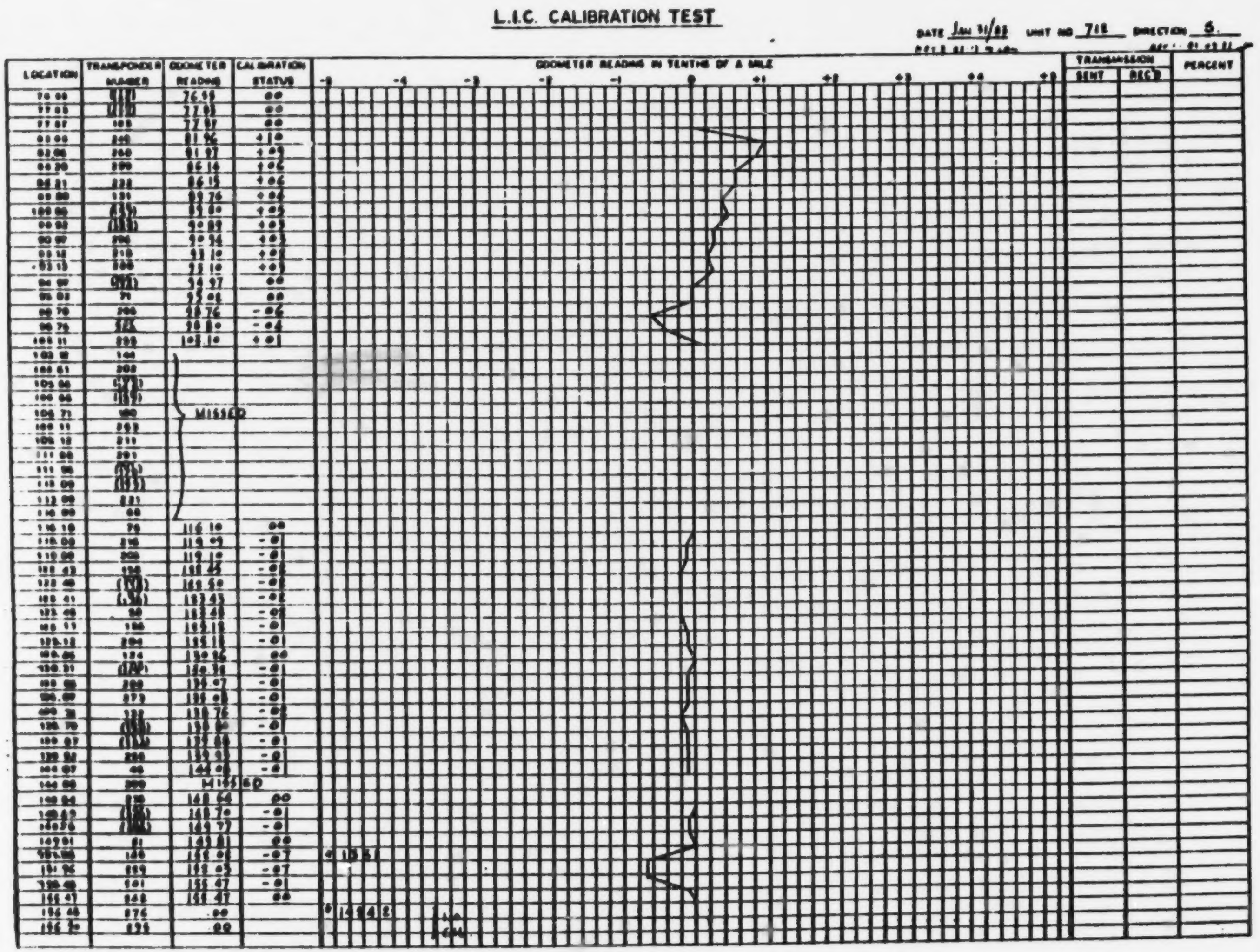


FIGURE F-4 (v)



L.I.C. CALIBRATION TEST

DATE Jan 31/83 UNIT NO 718 DIRECTION S.

FIGURE F-4 (w)

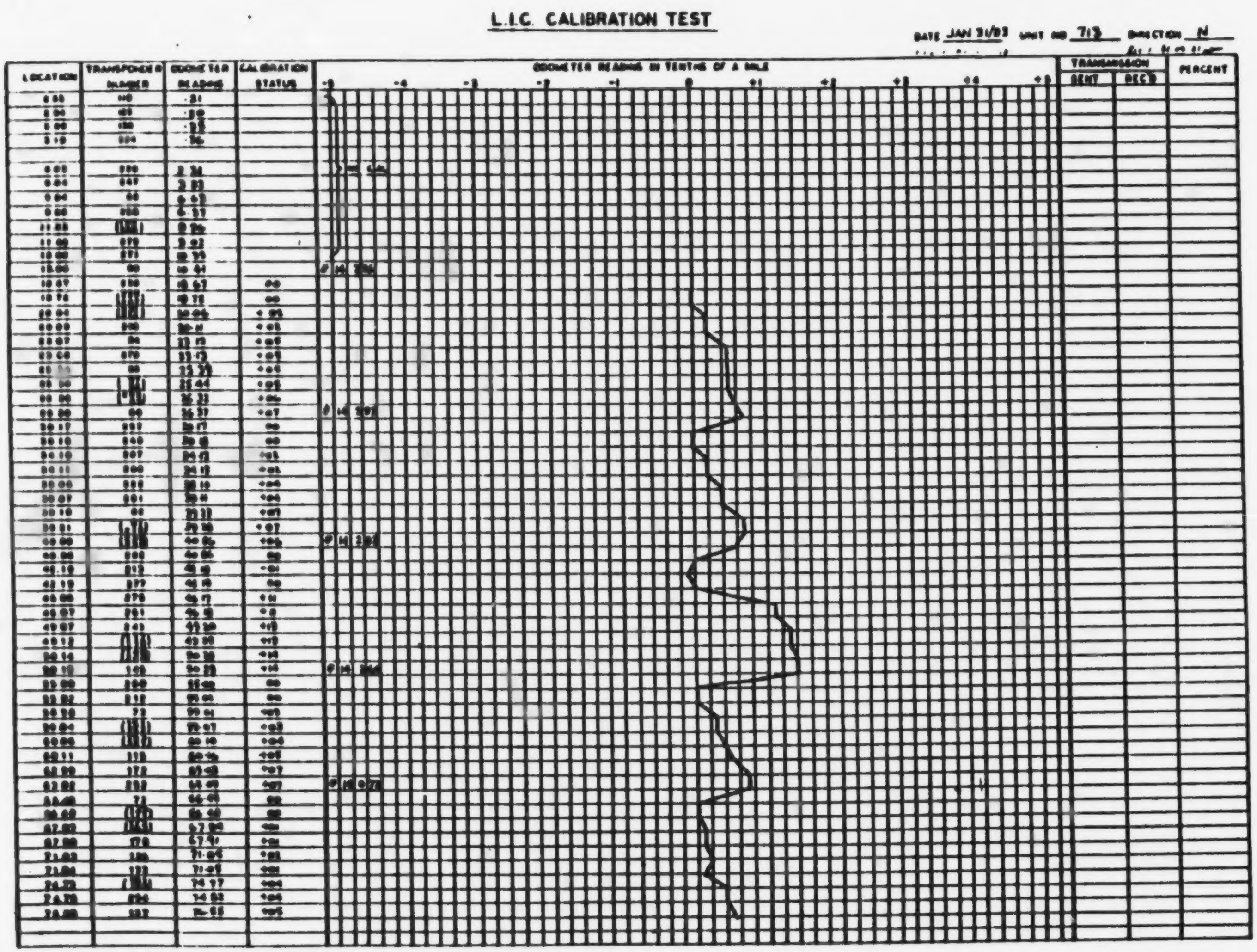

L.I.C. CALIBRATION TEST
DATE JAN 31/83
UNIT NO 713
DIRECTION N
LOCATION
TRANSPONDER NUMBER
ODOMETER READING
CALIBRATION STATUS
ODOMETER READING IN TENTHS OF A MILE
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
TRANSMISSION
SENT
REC'D
PERCENT

FIGURE F-4 (x)

L.I.C. CALIBRATION TEST

DATE Jan 31/83. UNIT NO 713 DIRECTION N

LOCATION	TRANSPONDER NUMBER	ODOMETER READING	CALIBRATION STATUS	TRANSMISSION SENT	TRANSMISSION REC'D	PERCENT
[illegible]	[illegible]	76.60	+05			
[illegible]	[illegible]	77.86	+05			
[illegible]	103	77.92	+05			
[illegible]	240	[illegible]	00			
[illegible]	260	[illegible]	00			
[illegible]	290	[illegible]	+03			
[illegible]	[illegible]	[illegible]	+03			
[illegible]	131	[illegible]	+03			
[illegible]	[illegible]	89.90	+05			
[illegible]	[illegible]	90.98	+06			
[illegible]	[illegible]	91.03	+06			
[illegible]	316	91.19	+07			
[illegible]	308	93.20	+07			
[illegible]	[illegible]	95.07	+10			
[illegible]	71	95.09	00			
[illegible]	[illegible]	[illegible]	+07			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	255	103.11	00			
[illegible]	146	103.11	-01			
[illegible]	203	[illegible]	00			
[illegible]	[illegible]	[illegible]	+02			
[illegible]	[illegible]	106.67	+01			
[illegible]	[illegible]	106.78	+01			
[illegible]	[illegible]	109.16	+01			
[illegible]	[illegible]	109.15	+03			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	[illegible]	[illegible]	+07			
[illegible]	[illegible]	[illegible]	+13			
[illegible]	66	116.17	+08			
[illegible]	75	[illegible]	+08			
[illegible]	[illegible]	[illegible]	+10			
[illegible]	[illegible]	[illegible]	+10			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	00			
[illegible]	204	[illegible]	00			
[illegible]	184	[illegible]	+03			
[illegible]	[illegible]	[illegible]	+04			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	272	[illegible]	+06			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	-01			
[illegible]	[illegible]	[illegible]	00			
[illegible]	[illegible]	[illegible]	-01			
[illegible]	49	[illegible]	+01			
[illegible]	[illegible]	MISSED				
[illegible]	[illegible]	[illegible]	+06			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	[illegible]	[illegible]	+05			
[illegible]	81	[illegible]	+05			
[illegible]	148	[illegible]	+06			
[illegible]	[illegible]	[illegible]	+06			
[illegible]	201	[illegible]	00			
[illegible]	248	[illegible]	00			
[illegible]	276	[illegible]	+01			
[illegible]	[illegible]	[illegible]	00			

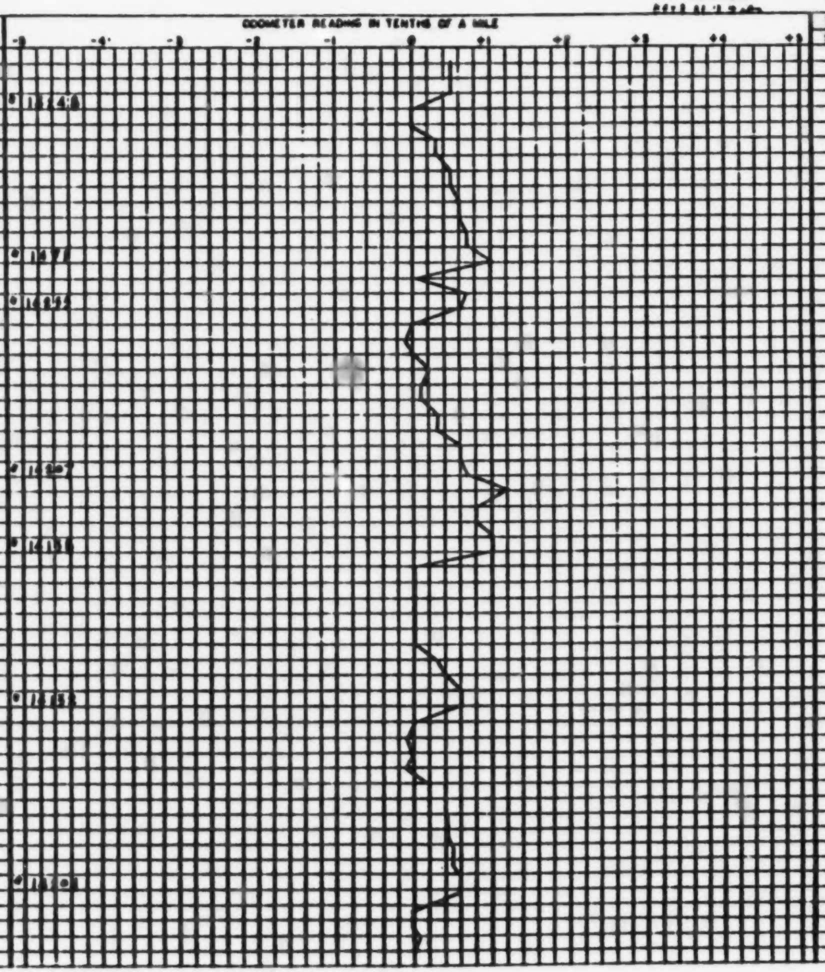


FIGURE F-4 (y)

L.I.C CALIBRATION TEST

DATE JAN31/83 UNIT NO 707 DIRECTION S

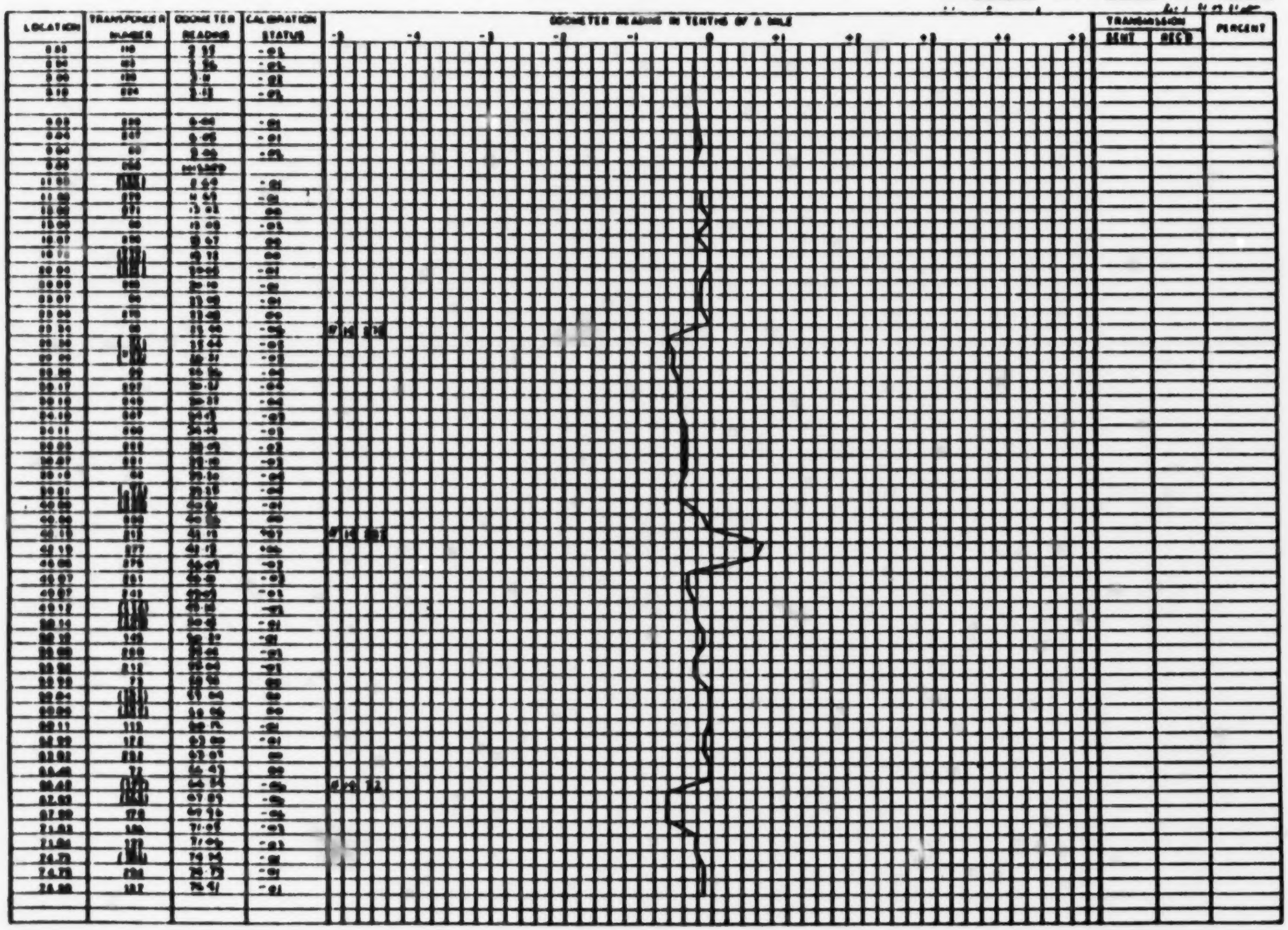
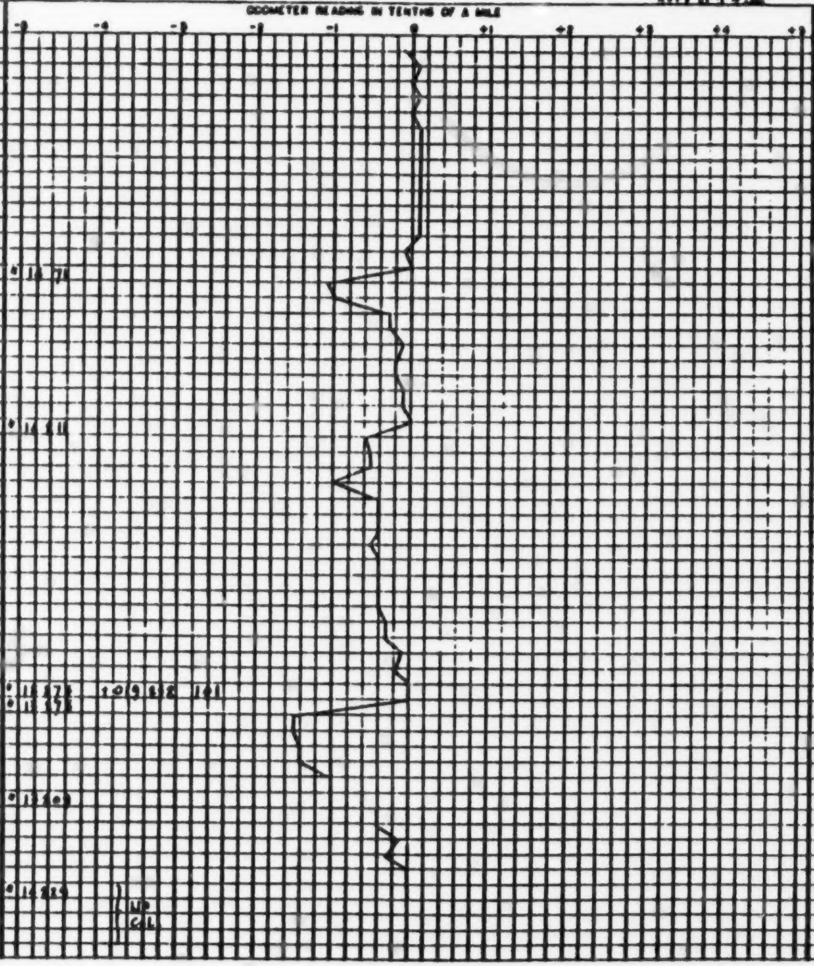


FIGURE F-4 (z)

L.I.C. CALIBRATION TEST

DATE Jan. 31/83. UNIT NO 707 DIRECTION S.



LOCATION	TRANSPONDER NUMBER	ODOMETER READING	CALIBRATION STATUS	TRANSMISSION SENT	TRANSMISSION REC'D	PERCENT
76 90	[illegible]	76 96	-01			
77 88	[illegible]	77 91	+01			
77 87	103	77 87	00			
81 00	240	81 09	+01			
82 06	260	82 06	00			
86 20	209	86 19	+01			
86 21	122	86 20	+01			
89 80	131	89 79	+01			
[illegible]	[illegible]	89 84	+01			
90 92	[illegible]	90 91	+01			
90 97	206	90 96	+01			
93 12	218	93 11	+01			
93 13	268	93 12	+01			
94 97	(103)	94 98	-01			
95 08	71	95 08	00			
98 70	200	98 81	-11			
98 76	126	98 86	-10			
103 11	232	103 14	-03			
103 12	144	103 15	-03			
105 61	202	105 62	-01			
105 66	(173)	105 68	-02			
106 66	(135)	106 68	-02			
106 71	180	106 72	-01			
109 11	263	109 12	-01			
109 12	211	109 12	00			
111 88	201	111 94	-06			
111 95	(126)	112 00	-05			
115 09	(133)	115 14	-05			
115 09	171	115 19	-10			
116 09	66	116 13	-04			
116 10	79	116 14	-04			
119 08	276	119 12	-04			
119 09	208	119 14	-05			
122 43	136	122 47	-04			
122 48	(178)	122 52	-04			
123 41	(138)	123 45	-04			
123 46	80	123 50	-04			
125 11	186	125 14	-03			
125 12	204	125 15	-03			
130 06	124	130 07	-01			
130 31	(125)	130 33	-02			
135 66	209	135 66	00			
135 07	273	135 07	00			
138 78	138	138 93	-15			
138 79	(135)	138 94	-15			
139 87	(110)	140 01	-14			
139 82	236	140 96	-14			
144 07	46	144 17	-10			
146 86	209	MISSED				
148 64	128	148 68	-04			
148 69	(126)	148 73	-04			
149 76	(125)	149 77	-01			
149 81	81	149 84	-03			
151 95	198	151 95	00			
151 96	229	151 96	00			
155 46	201	.00				
155 47	248	.00				
155 48	276					
156 50	255					

FIGURE F-4 (aa)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATIONS REPORT

UNIT OR CAB 720 DATE Dec. 11/82 DIRECTION S

MILEAGE	CCS TRANSMISSIONS	ELU REPLIES	PERCENT
156.53	60	50	84%
151.78	35	31	89%
145.78	18	15	84%
135.30	15	11	74%
126.09	14	10	72%
121.02	20	13	65%
116.27	9	6	67%
111.35	24	18	75%
106.12	21	14	67%
101.46	16	12	75%
95.86	9	7	78%
91.38	22	22	100%
86.44	15	13	87%
80.41	23	15	66%
75.08	10	10	100%
71.30	11	11	100%

FIGURE F-5 (a)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATIONS REPORT

UNIT OR CAB 720 DATE Oct. 13/82 DIRECTION N.

MILEAGE	CCS TRANSMISSIONS	ELU REPLIES	PERCENT
5.54	98	94	96%
10.68	81	65	81%
15.58	62	39	63%
20.61	62	41	67%
25.58	68	54	80%
30.51	61	51	84%
35.50	67	54	81%.
40.55	73	35	89%
45.58	53	47	89%
53.00	42	17	41%
55.93	41	22	54%
60.52	66	49	75%
65.56	77	64	84%
70.55	71	68	96%
75.53	64	64	100%
80.55	54	51	95%

FIGURE F-5 (b)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATIONS REPORT

UNIT OR CAB 720 DATE DEC 17/84 DIRECTION N

MILEAGE	CCS TRANSMISSIONS	ELC REPLIES	PERCENT
.23	4	4	100%
.09	47	47	100%
6.04	52	44	85%
11.63	62	44	71%
15.58	33	28	85%
20.50	61	44	73%
25.72	46	37	81%
30.61	37	33	90%
35.50	34	27	80%
40.55	46	37	81%
45.81	33	31	94%
51.77	54	18	34%
55.51	32	25	78%
61.05	3	3	100%
65.50	49	41	84%
70.54	39	36	93%

FIGURE F-5 (c)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT Bc 10

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 1/82	N	1315	919	70%	100%
✓ 2/82	N	1573	1093	69.4%	100%
✓ 2/82	S	1457	1051	72%	100%
✓ 7/82	N	1196	816	68%	100%
✓ 8/82	S	1971	1418	72%	100%
✓ 9/82	N	2126	1461	69%	100%
✓ ✓	S	1487	1014	69%	✓
✓ 10/82	N	702	483	69%	✓
✓ 20/82	S	4813	3835	78%	100%
✓ 21/82	S	7387	5412	74%	✓
✓ 22/82	N	2236	1478	66%	✓
		26263	18980	72.2%	

FIGURE F-5 (d)

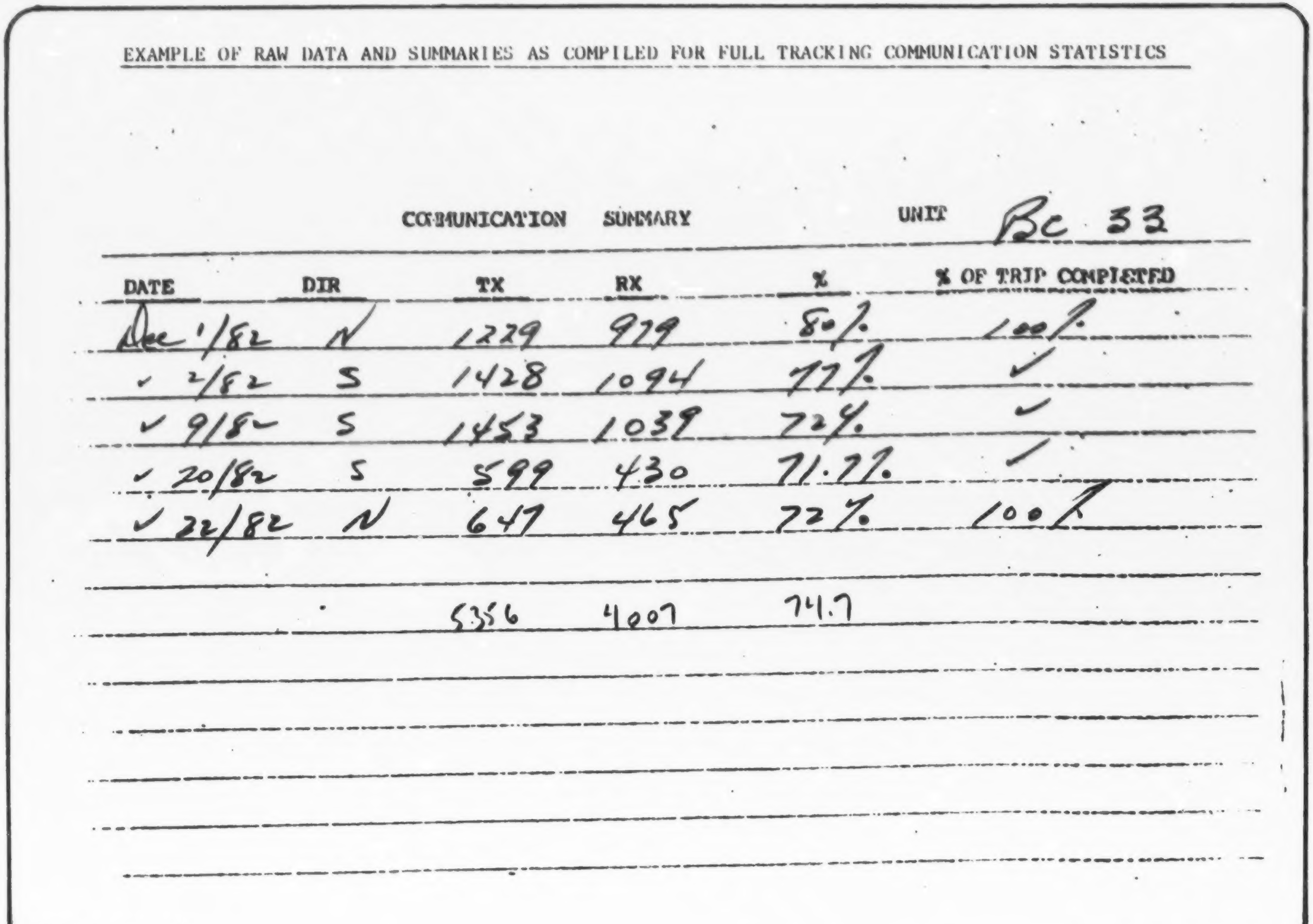
EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT Bc 31

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 20/82	S	545	420	77%	100%
〃 22/82	N	1492	1127	76%	✓
		2037	1547	75.9	

FIGURE F-5 (e)



EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT Bc 33

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 1/82	N	1229	979	80%	100%
✓ 2/82	S	1428	1094	77%	✓
✓ 9/82	S	1453	1039	72%	✓
✓ 20/82	S	599	430	71.7%	✓
✓ 22/82	N	647	465	72%	100%
		5356	4007	74.7	

FIGURE F-5 (f)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY **UNIT** 103

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 22/82	S	1577	920	58%	100%

FIGURE F-5 (g)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 707

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 2/82	N	2082	1578	76%	100%
9/82	N	1541	1096	71%	100%
–	S	2938	2191	75%	–
13/82	N	2426	1765	72%	100%
19/82	N	1810	1294	71%	–
		10797	7924	73.3	

FIGURE F-5 (h)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 709

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 9/82	N	1527	1155	76%	100%
✓	S	3112	2558	82%	✓
19/82	N	1696	1332	79%	✓
		6335	5045	79.6	

FIGURE F-5 (1)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 7/10

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 2/82	N	2158	1602	74%	100%
✓ 9/82	N	1514	1153	76%	✓
✓ 13/82	S	2774	2139	77%	100%
✓ 18/82	N	1806	1320	73%	100%
		8252	6214	75.3	

FIGURE F-5 (j)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY **UNIT** 712

DATE	**DIR**	**TX**	**RX**	**%**	**% OF TRIP COMPLETED**
Dec 2/82	N	2127	1637	77%	100%
✓ 9/82	–	1538	1123	73%	✓
✓ 9/82	S	2827	2041	72%	✓
✓ 13/82	S	2744	2116	77%	✓
		9236	6917	74.9	

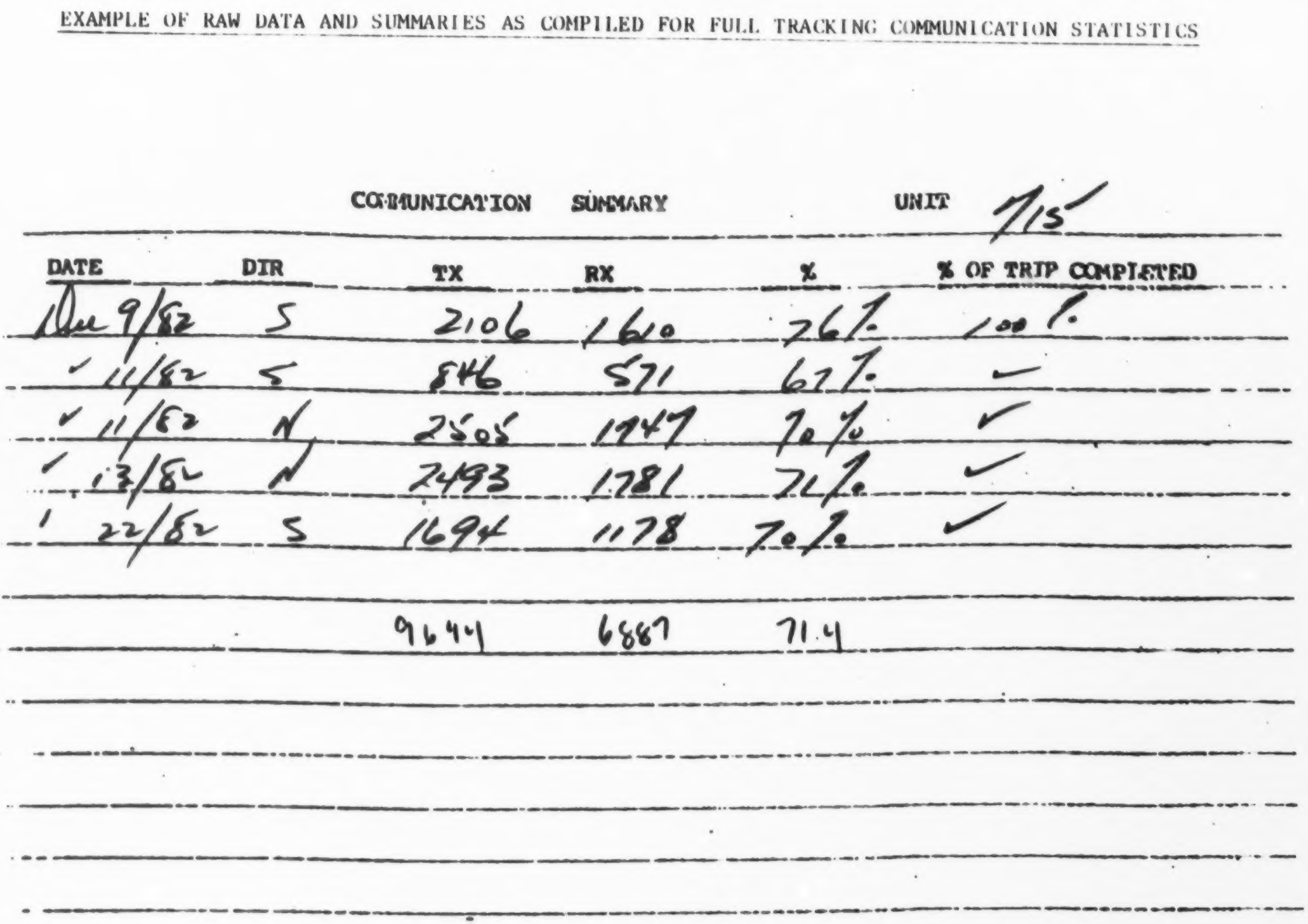
FIGURE F-5 (k)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 713

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 1/82	S	3934	2862	73%	100%
✓ 11/82	S	811	582	72%	✓
✓ 13/82	N	2468	1769	72%	✓
✓ 13/82	N	1951	1350	69%	✓
✓ 17/82	N	1450	1050	72%	✓
		10614	7613	717	

FIGURE F-5 (1)

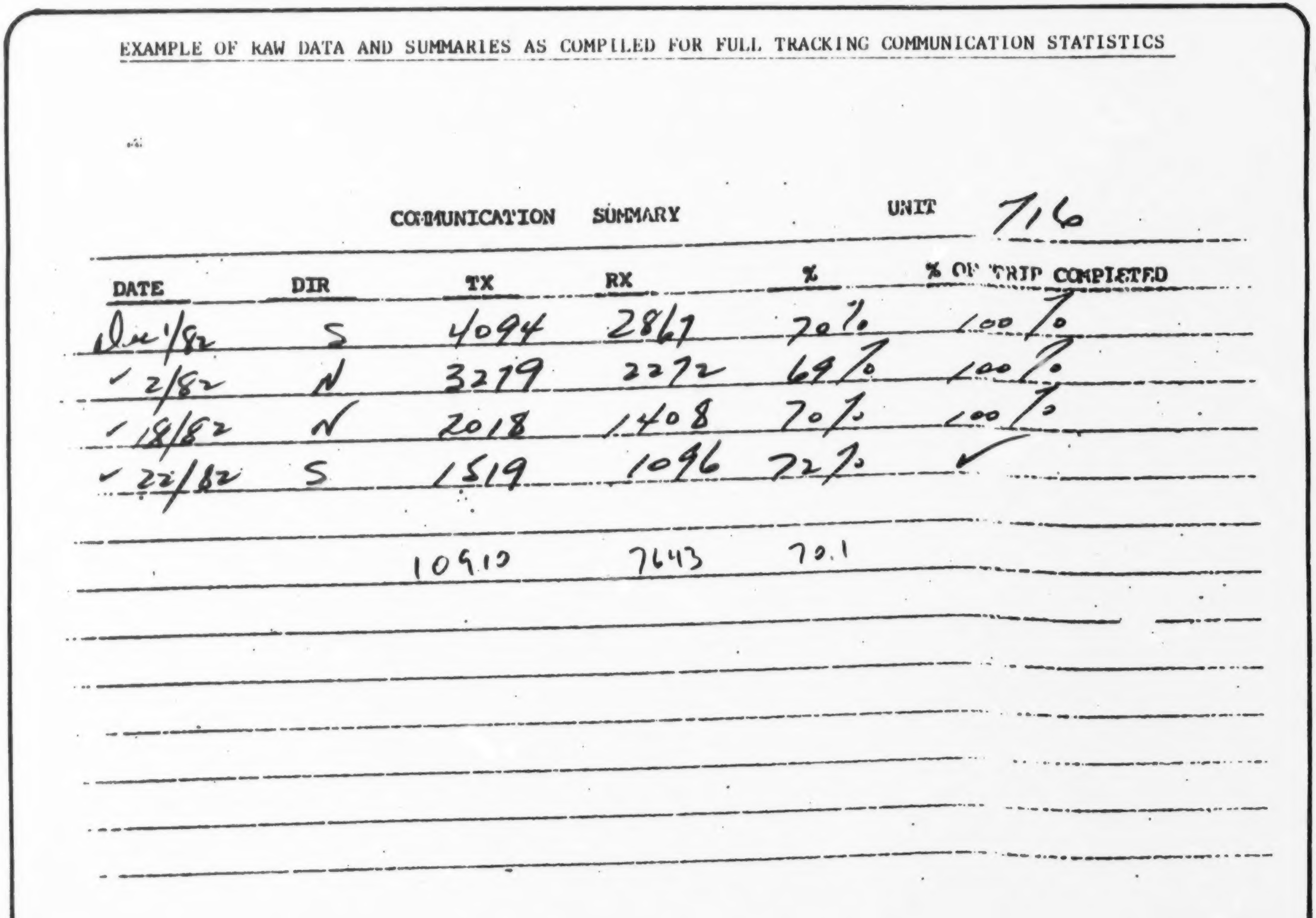


EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 7/15

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 9/82	S	2106	1610	76%	100%
〃 11/82	S	846	571	67%	✓
〃 11/82	N	2505	1947	70%	✓
〃 13/82	N	2493	1781	72%	✓
〃 22/82	S	1694	1178	70%	✓
		9644	6887	71.4	

FIGURE F-5 (m)



EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 716

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 1/82	S	4094	2867	70%	100%
✓ 2/82	N	3279	2272	69%	100%
✓ 18/82	N	2018	1408	70%	100%
✓ 22/82	S	1519	1096	72%	✓
		10910	7643	70.1	

FIGURE F-5 (n)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 7/1

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 2/82	N	2319	1546	67%	100%
✓ 11/82	S	853	529	62%	100%
✓ 11/82	N	2513	1604	63%	100%
✓ 18/82	N	2183	1403	64%	100%
✓ 22/82	S	1567	999	64%	✓
		9435	6081	64.5	

FIGURE F-5 (o)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 7/9

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 10/82	S	1654	1066	65%	100%
✓ ✓	N	1974	1343	68%	100%
✓ 19/82	N	1863	1257	67%	100%
		5491	3666	66.8	

FIGURE F-5 (p)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 720

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 11/82	S	757	585	77%	100%
" 13/82	N	2222	1805	82%	100%
" 17/82	N	1348	1065	79%	100%
		4327	3455	79.8	

FIGURE F-5 (q)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 721

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 4/82	N	1783	1350	76%	100%
8/82	N	2573	1869	73%	100%
		4356	3219	73.9	

FIGURE F-5 (r)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 722

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 8/82	N	2692	1704	63%	100%
✓ 13/82	N	1878	1193	64%	100%
- 22/82	S	1569	952	61%	100%
		6139	3849	627	

FIGURE F-5 (s)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 1858

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 2/82	S	1787	1450	81%	100%
		27401	19844	72.4%	cabooses

FIGURE F-5 (t)

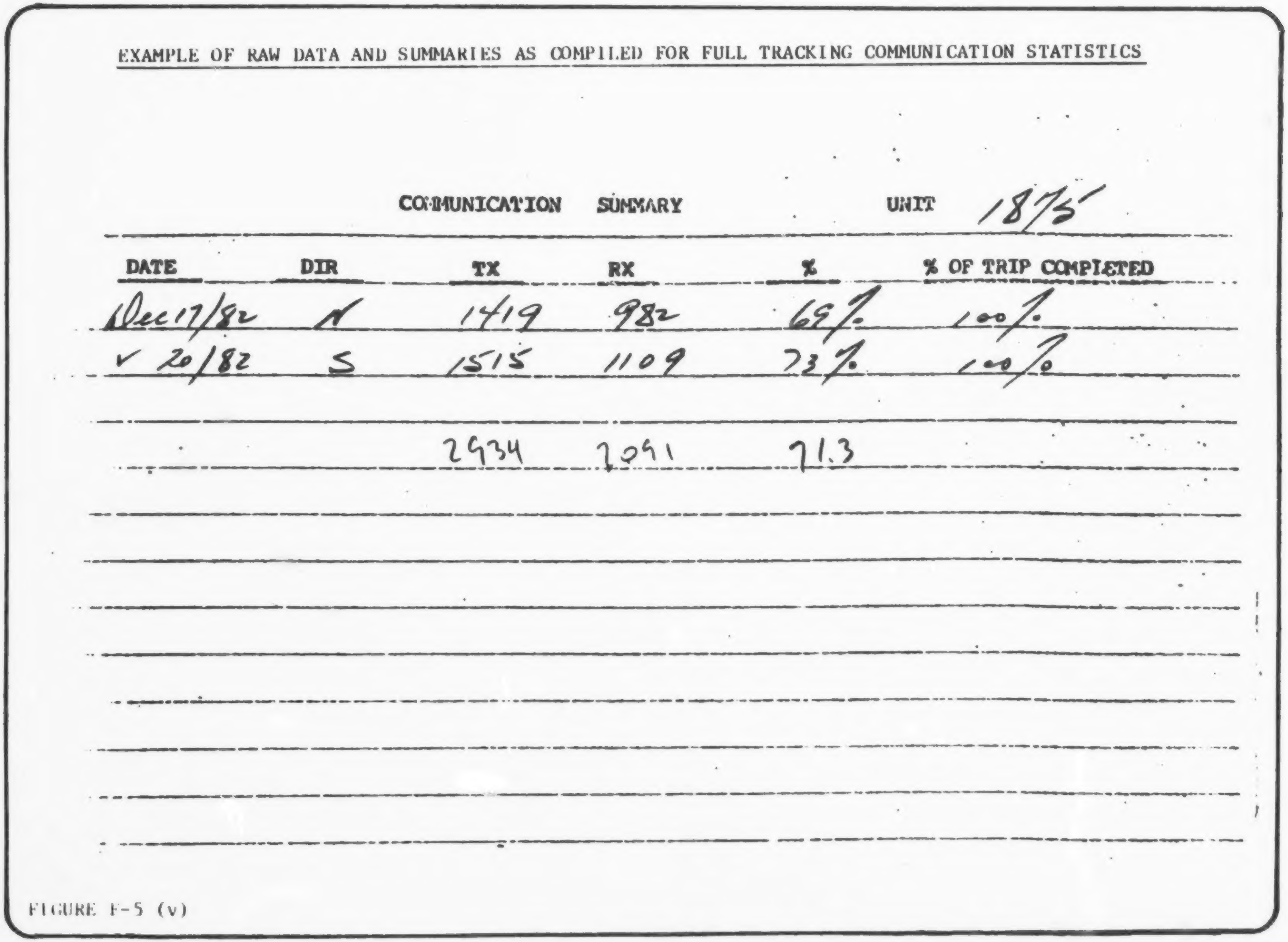
EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 1860

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 13/82	S	2604	1977	76%	100%
" 18/82	N	1771	1410	80%	✓
" 21/82	S	1892	1347	71%	100%
		6267	4734	75.5	

FIGURE F-5 (u)



EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 1875

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 17/82	N	1419	982	69%	100%
✓ 20/82	S	1515	1109	73%	100%
		2934	2091	71.3	

FIGURE F-5 (v)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 1878

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 8/82	N	2325	1746	75%	100%
- 13/82	N	2146	1693	79%	100%
' 19/82	N	1501	1241	83%	100%
		5972	4680	78.4	

FIGURE F-5 (w)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT 1879

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 10/82	N	1836	1343	73%	100%

FIGURE F-5 (x)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT 1881

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 2/82	N	2961	2018	68%	100%
〃 9/82	N	3159	2101	67%	100%
〃 22/82	S	2485	1427	57%	100% SQUAM WAYEBT
		8605	5546	645	

FIGURE F-5 (y)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY UNIT BC12

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 10/82	N	565	372	66%	100%

FIGURE F-5 (z)

EXAMPLE OF RAW DATA AND SUMMARIES AS COMPILED FOR FULL TRACKING COMMUNICATION STATISTICS

COMMUNICATION SUMMARY

UNIT Bell

DATE	DIR	TX	RX	%	% OF TRIP COMPLETED
Dec 1/82	N	1358	909	67%	100%
2/82	S	1540	1064	69%	✓
9/82	S	1614	1063	66%	✓
10/82	N	753	450	60%	100%
		5265	3486	66.2	

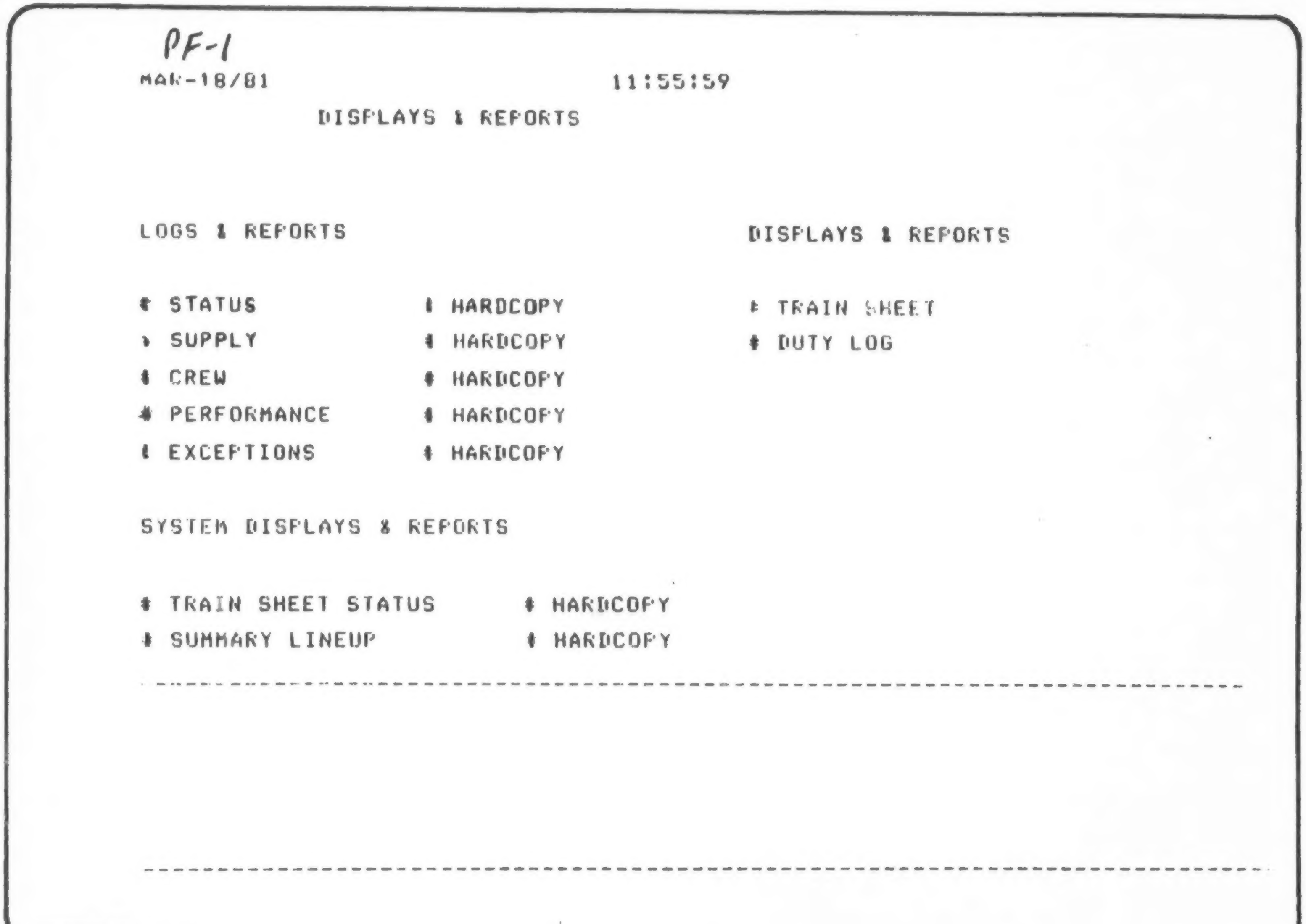
FIGURE F-5 (aa)

APPENDIX G

LOCATION, IDENTIFICATION AND CONTROL SYSTEM

DISPATCHER REPORTS AND DISPLAYS
AVAILABLE ON VT-100 TERMINAL

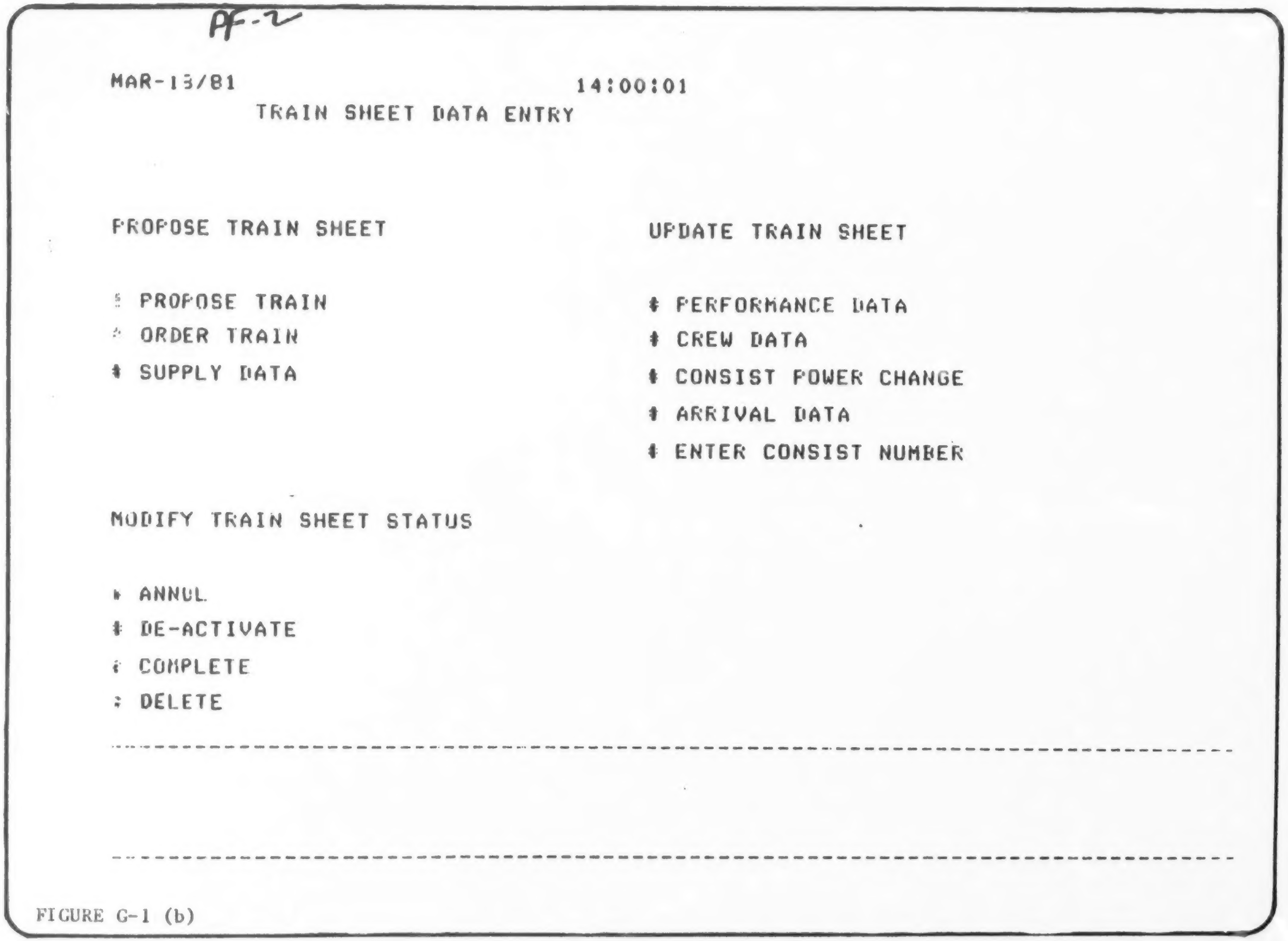
BRITISH COLUMBIA RAILWAY



PF-1

```
MAR-18/81                         11:55:59
          DISPLAYS & REPORTS


LOGS & REPORTS                                  DISPLAYS & REPORTS

# STATUS            # HARDCOPY                  # TRAIN SHEET
# SUPPLY            # HARDCOPY                  # DUTY LOG
# CREW              # HARDCOPY
# PERFORMANCE       # HARDCOPY
# EXCEPTIONS        # HARDCOPY

SYSTEM DISPLAYS & REPORTS

# TRAIN SHEET STATUS     # HARDCOPY
# SUMMARY LINEUP         # HARDCOPY
----------------------------------------------------------------------------



----------------------------------------------------------------------------
```

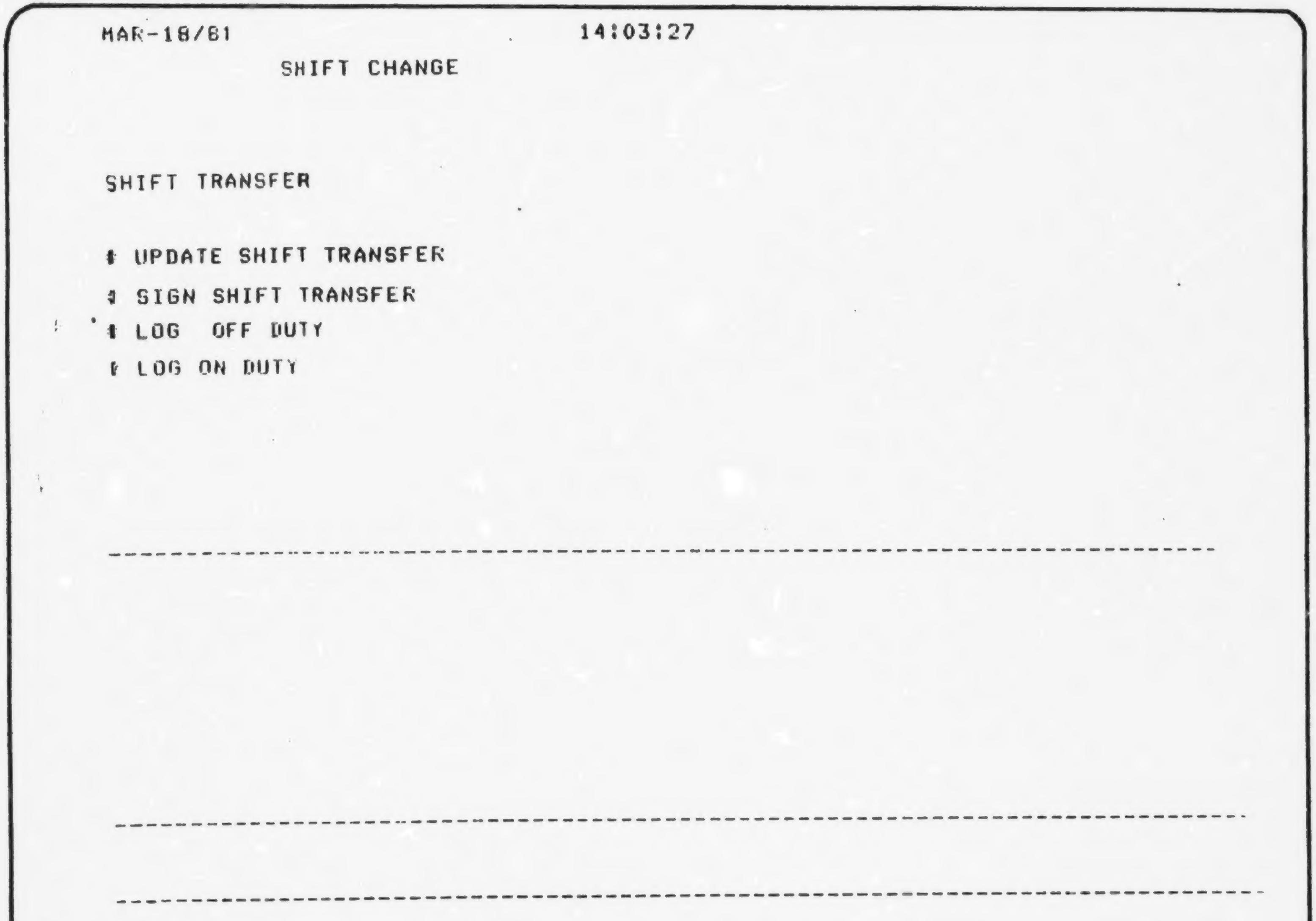
FIGURE G-1 (a)



AF-2

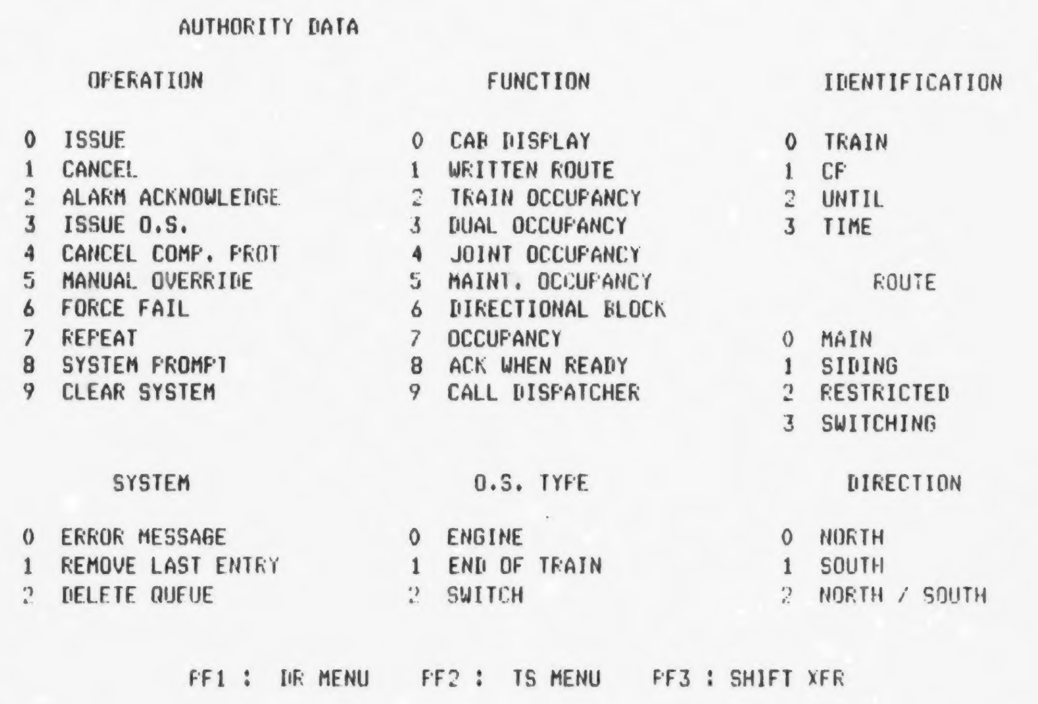
```
MAR-13/81                              14:00:01
        TRAIN SHEET DATA ENTRY


PROPOSE TRAIN SHEET                         UPDATE TRAIN SHEET

# PROPOSE TRAIN                             # PERFORMANCE DATA
# ORDER TRAIN                               # CREW DATA
# SUPPLY DATA                               # CONSIST POWER CHANGE
                                            # ARRIVAL DATA
                                            # ENTER CONSIST NUMBER

MODIFY TRAIN SHEET STATUS

# ANNUL
# DE-ACTIVATE
# COMPLETE
# DELETE
------------------------------------------------------------------


------------------------------------------------------------------
```

FIGURE G-1 (b)



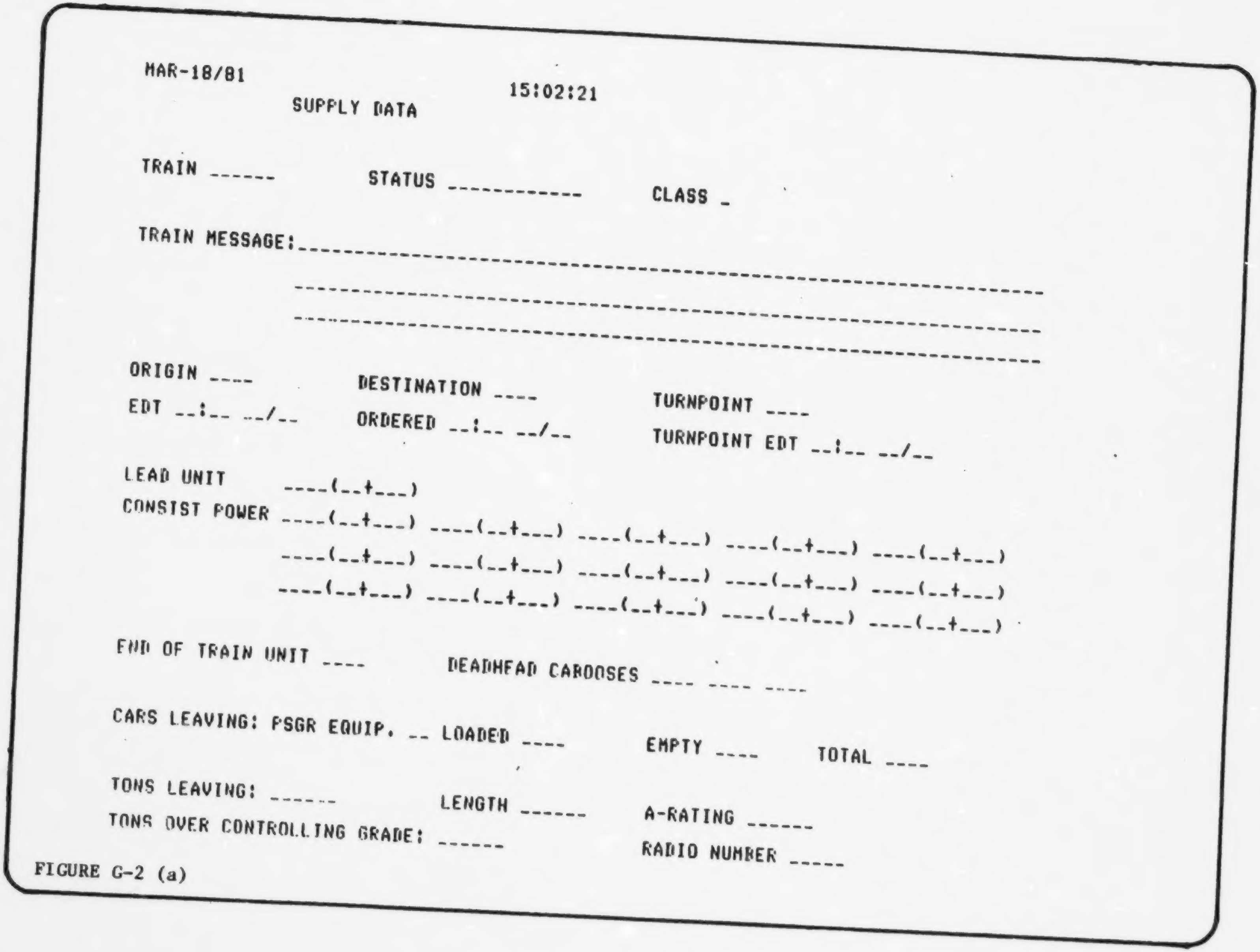
```
MAR-18/81                              14:03:27
          SHIFT CHANGE


SHIFT TRANSFER

# UPDATE SHIFT TRANSFER
# SIGN SHIFT TRANSFER
# LOG  OFF DUTY
# LOG ON DUTY




----------------------------------------------------------------------------




-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
```

FIGURE G-1 (c)



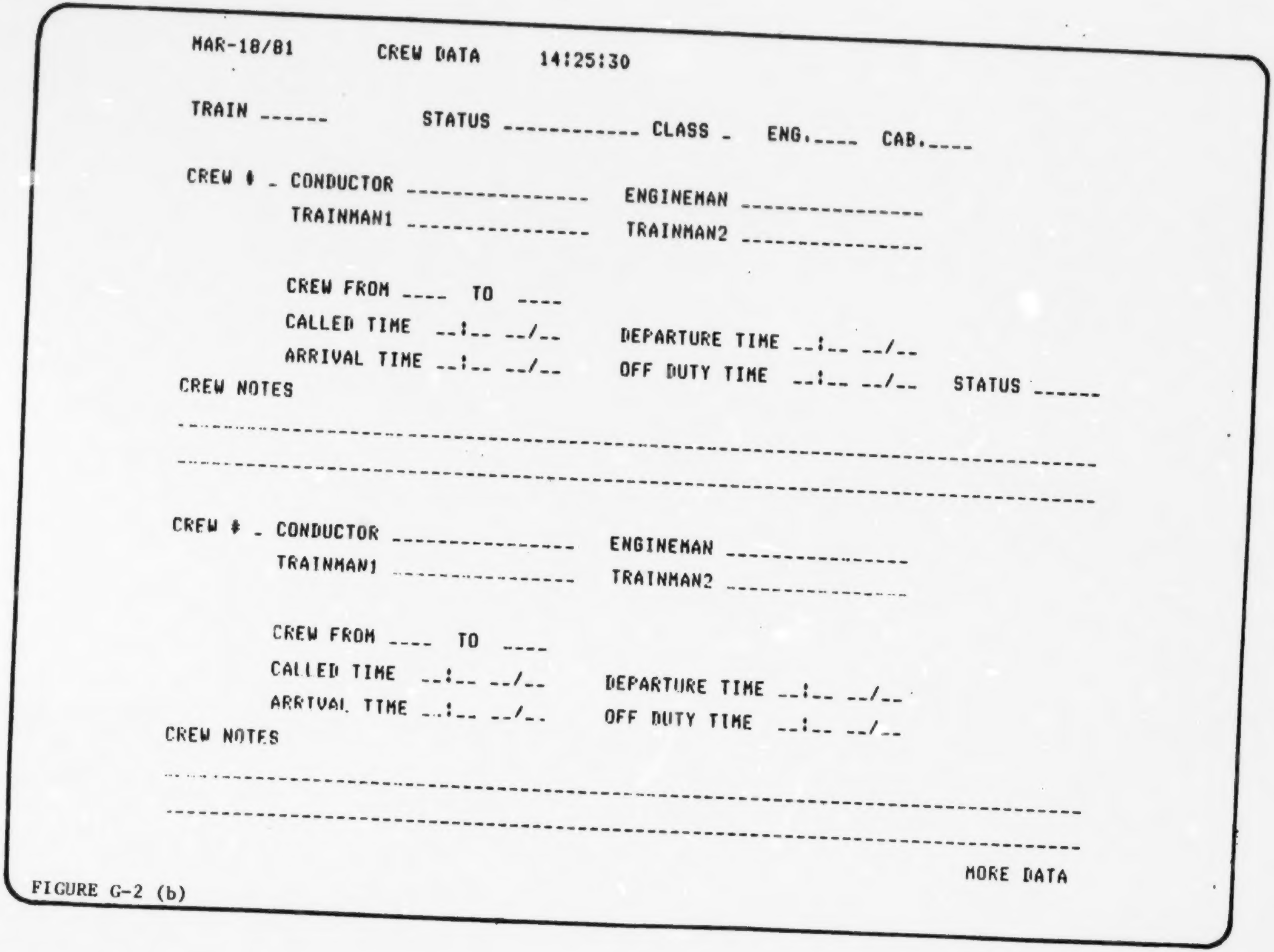
```
                 AUTHORITY DATA

          OPERATION                FUNCTION                IDENTIFICATION

    0  ISSUE                  0  CAB DISPLAY             0  TRAIN
    1  CANCEL                 1  WRITTEN ROUTE           1  CP
    2  ALARM ACKNOWLEDGE      2  TRAIN OCCUPANCY         2  UNTIL
    3  ISSUE O.S.             3  DUAL OCCUPANCY          3  TIME
    4  CANCEL COMP. PROT      4  JOINT OCCUPANCY
    5  MANUAL OVERRIDE        5  MAINT. OCCUPANCY              ROUTE
    6  FORCE FAIL             6  DIRECTIONAL BLOCK
    7  REPEAT                 7  OCCUPANCY               0  MAIN
    8  SYSTEM PROMPT          8  ACK WHEN READY          1  SIDING
    9  CLEAR SYSTEM           9  CALL DISPATCHER         2  RESTRICTED
                                                         3  SWITCHING

           SYSTEM                  O.S. TYPE                DIRECTION

    0  ERROR MESSAGE          0  ENGINE                  0  NORTH
    1  REMOVE LAST ENTRY      1  END OF TRAIN            1  SOUTH
    2  DELETE QUEUE           2  SWITCH                  2  NORTH / SOUTH

                 PF1 :  DR MENU    PF2 :  TS MENU    PF3 : SHIFT XFR
```

FIGURE G-1 (d)



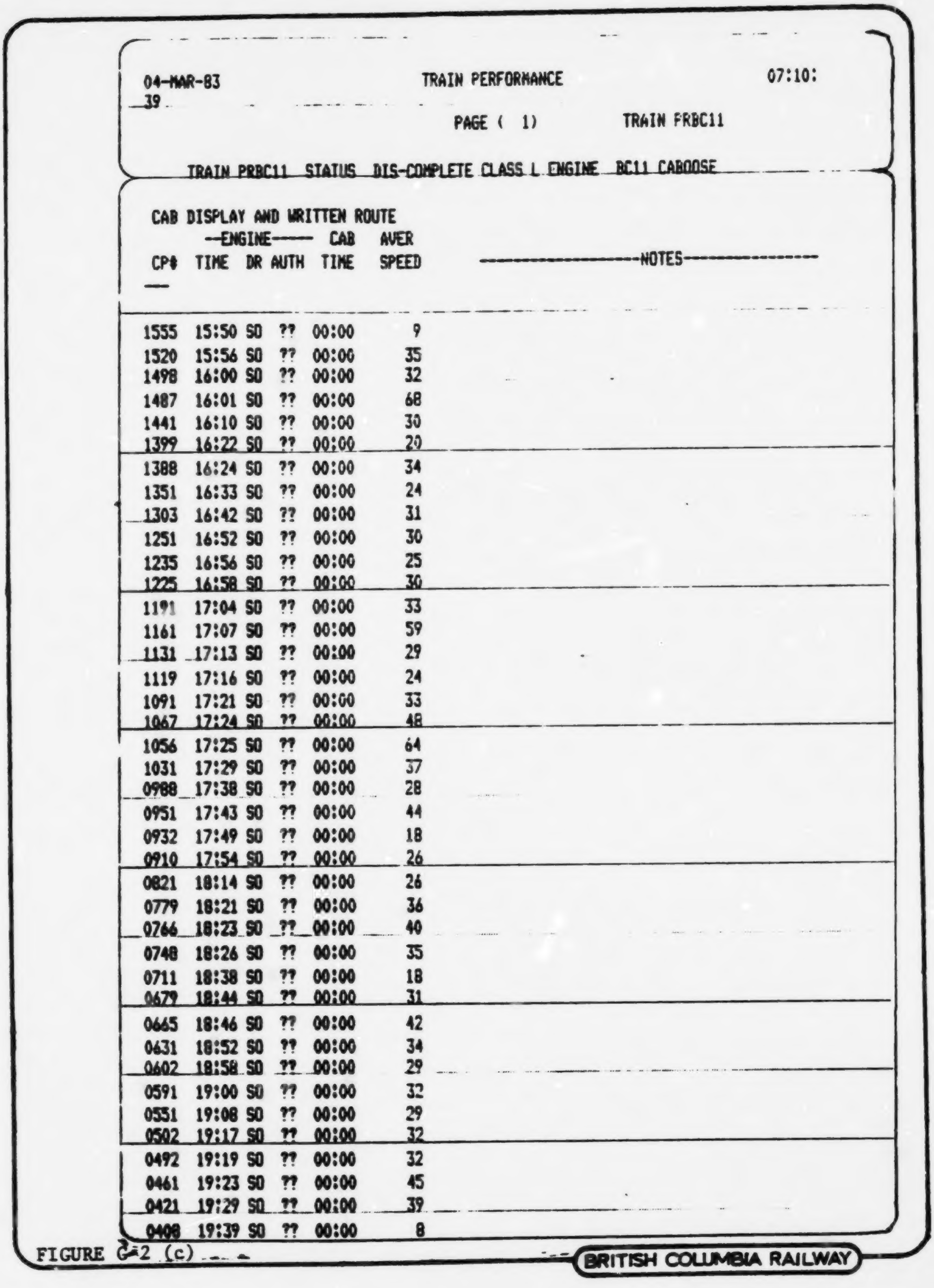
```
MAR-18/81                            15:02:21
               SUPPLY DATA

TRAIN ------        STATUS -----------       CLASS _

TRAIN MESSAGE:----------------------------------------------------------
              ----------------------------------------------------------
              ----------------------------------------------------------

ORIGIN ----         DESTINATION ----         TURNPOINT ----
EDT --:-- --/--     ORDERED --:-- --/--      TURNPOINT EDT --:-- --/--

LEAD UNIT      ----(--+---)
CONSIST POWER ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
              ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
              ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)

END OF TRAIN UNIT ----     DEADHEAD CABOOSES ---- ---- ----

CARS LEAVING: PSGR EQUIP. -- LOADED ----      EMPTY ----    TOTAL ----

TONS LEAVING: ------       LENGTH ------     A-RATING ------
TONS OVER CONTROLLING GRADE: ------          RADIO NUMBER -----
```

FIGURE G-2 (a)



```
MAR-18/81       CREW DATA     14:25:30

TRAIN ------        STATUS ------------ CLASS -   ENG.----  CAB.----

CREW # - CONDUCTOR ---------------   ENGINEMAN ---------------
         TRAINMAN1 ---------------   TRAINMAN2 ---------------

         CREW FROM ----  TO  ----
         CALLED TIME  --:-- --/--    DEPARTURE TIME --:-- --/--
         ARRIVAL TIME --:-- --/--    OFF DUTY TIME  --:-- --/--   STATUS ------
CREW NOTES
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------

CREW # - CONDUCTOR ---------------   ENGINEMAN ---------------
         TRAINMAN1 ---------------   TRAINMAN2 ---------------

         CREW FROM ----  TO  ----
         CALLED TIME  --:-- --/--    DEPARTURE TIME --:-- --/--
         ARRIVAL TIME --:-- --/--    OFF DUTY TIME  --:-- --/--
CREW NOTES
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
                                                                       MORE DATA
```

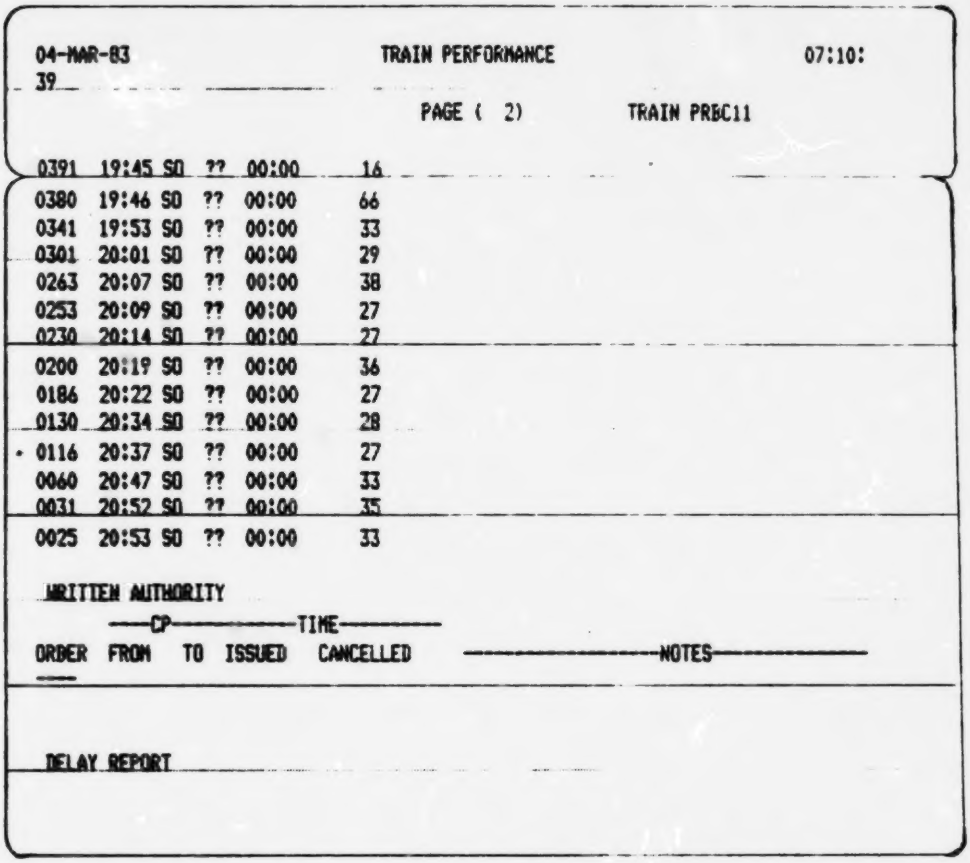
FIGURE G-2 (b)



```
04-MAR-83                         TRAIN PERFORMANCE                      07:10:
39
                                      PAGE (  1)          TRAIN FRBC11

      TRAIN PRBC11  STATUS  DIS-COMPLETE CLASS L ENGINE  BC11 CABOOSE

 CAB DISPLAY AND WRITTEN ROUTE
      --ENGINE-----  CAB   AVER
 CP#  TIME  DR AUTH  TIME  SPEED         ------------------NOTES-----------------
 ---

1555  15:50 SO  ??  00:00     9
1520  15:56 SO  ??  00:00    35
1498  16:00 SO  ??  00:00    32
1487  16:01 SO  ??  00:00    68
1441  16:10 SO  ??  00:00    30
1399  16:22 SO  ??  00:00    20
1388  16:24 SO  ??  00:00    34
1351  16:33 SO  ??  00:00    24
1303  16:42 SO  ??  00:00    31
1251  16:52 SO  ??  00:00    30
1235  16:56 SO  ??  00:00    25
1225  16:58 SO  ??  00:00    30
1191  17:04 SO  ??  00:00    33
1161  17:07 SO  ??  00:00    59
1131  17:13 SO  ??  00:00    29
1119  17:16 SO  ??  00:00    24
1091  17:21 SO  ??  00:00    33
1067  17:24 SO  ??  00:00    48
1056  17:25 SO  ??  00:00    64
1031  17:29 SO  ??  00:00    37
0988  17:38 SO  ??  00:00    28
0951  17:43 SO  ??  00:00    44
0932  17:49 SO  ??  00:00    18
0910  17:54 SO  ??  00:00    26
0821  18:14 SO  ??  00:00    26
0779  18:21 SO  ??  00:00    36
0766  18:23 SO  ??  00:00    40
0748  18:26 SO  ??  00:00    35
0711  18:38 SO  ??  00:00    18
0679  18:44 SO  ??  00:00    31
0665  18:46 SO  ??  00:00    42
0631  18:52 SO  ??  00:00    34
0602  18:58 SO  ??  00:00    29
0591  19:00 SO  ??  00:00    32
0551  19:08 SO  ??  00:00    29
0502  19:17 SO  ??  00:00    32
0492  19:19 SO  ??  00:00    32
0461  19:23 SO  ??  00:00    45
0421  19:29 SO  ??  00:00    39
0408  19:39 SO  ??  00:00     8
```

FIGURE G-2 (c)

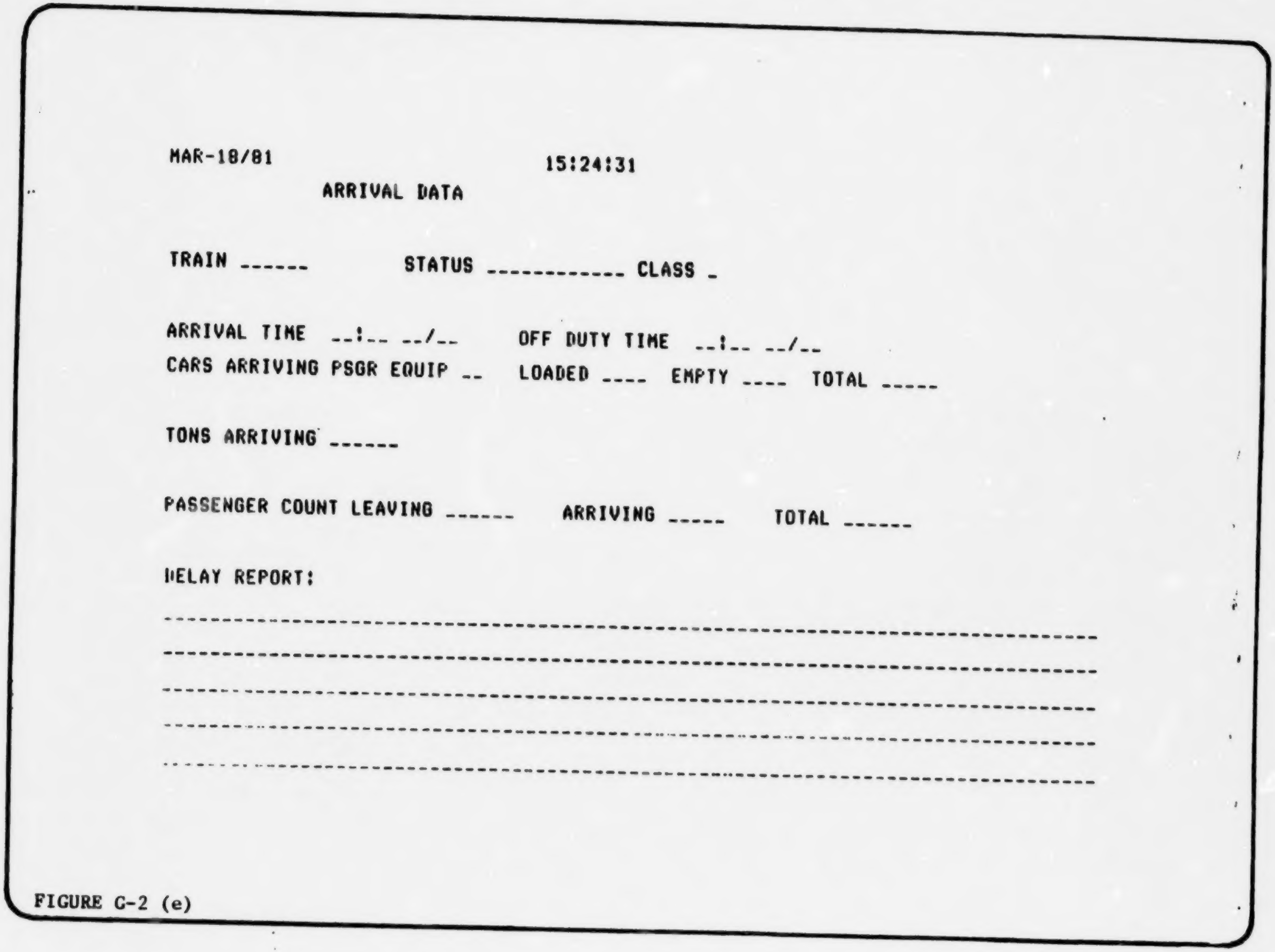
BRITISH COLUMBIA RAILWAY



```
04-MAR-83                              TRAIN PERFORMANCE                    07:10:
39
                                          PAGE (  2)        TRAIN PRBC11

0391  19:45 SO  ??  00:00      16
0380  19:46 SO  ??  00:00      66
0341  19:53 SO  ??  00:00      33
0301  20:01 SO  ??  00:00      29
0263  20:07 SO  ??  00:00      38
0253  20:09 SO  ??  00:00      27
0230  20:14 SO  ??  00:00      27
0200  20:19 SO  ??  00:00      36
0186  20:22 SO  ??  00:00      27
0130  20:34 SO  ??  00:00      28
0116  20:37 SO  ??  00:00      27
0060  20:47 SO  ??  00:00      33
0031  20:52 SO  ??  00:00      35
0025  20:53 SO  ??  00:00      33

WRITTEN AUTHORITY
       ----CP-----------TIME----------
ORDER  FROM   TO  ISSUED   CANCELLED      -----------------NOTES---------------
-----

DELAY REPORT
```

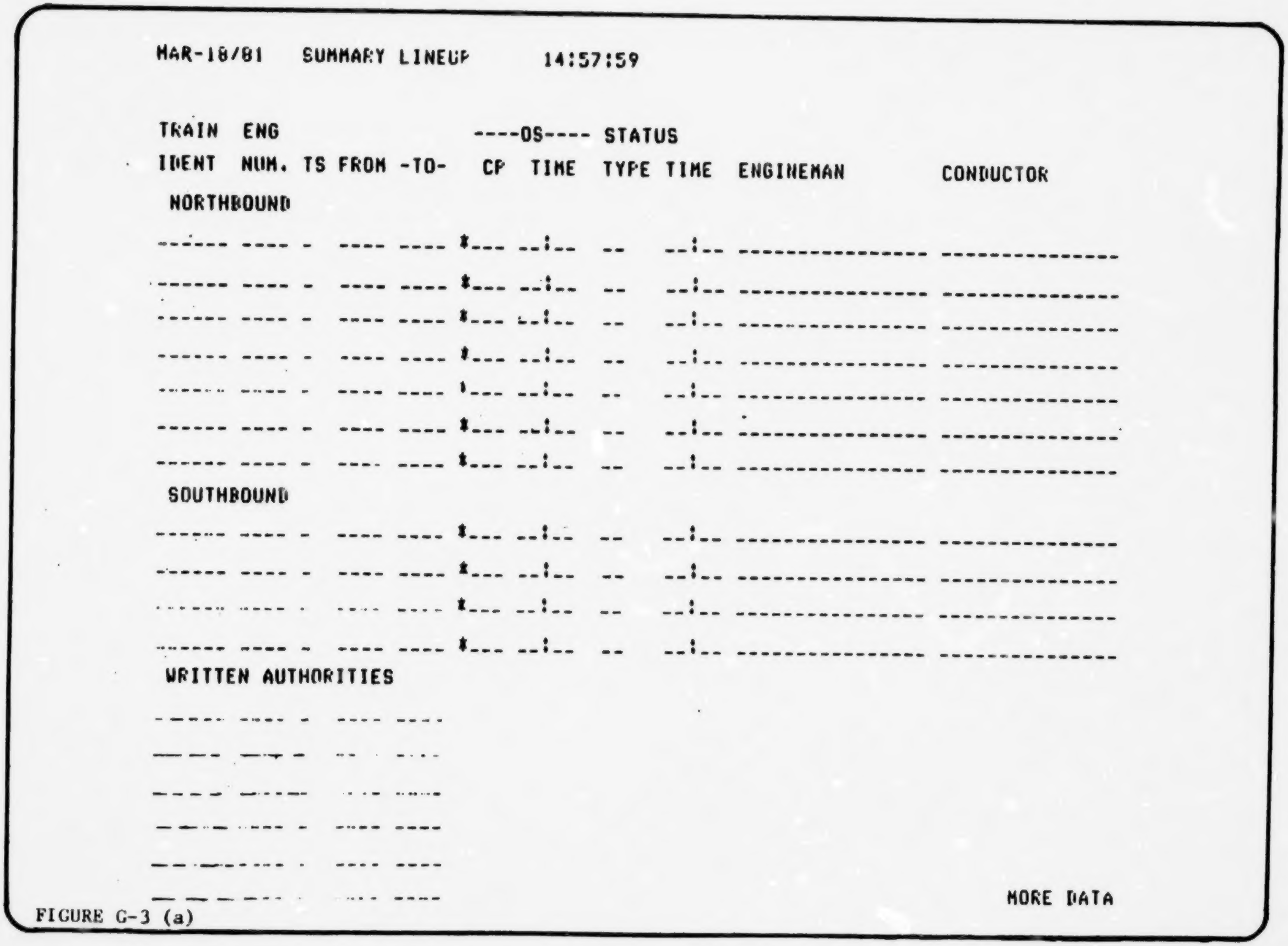
FIGURE G-2 (d)

BRITISH COLUMBIA RAILWAY



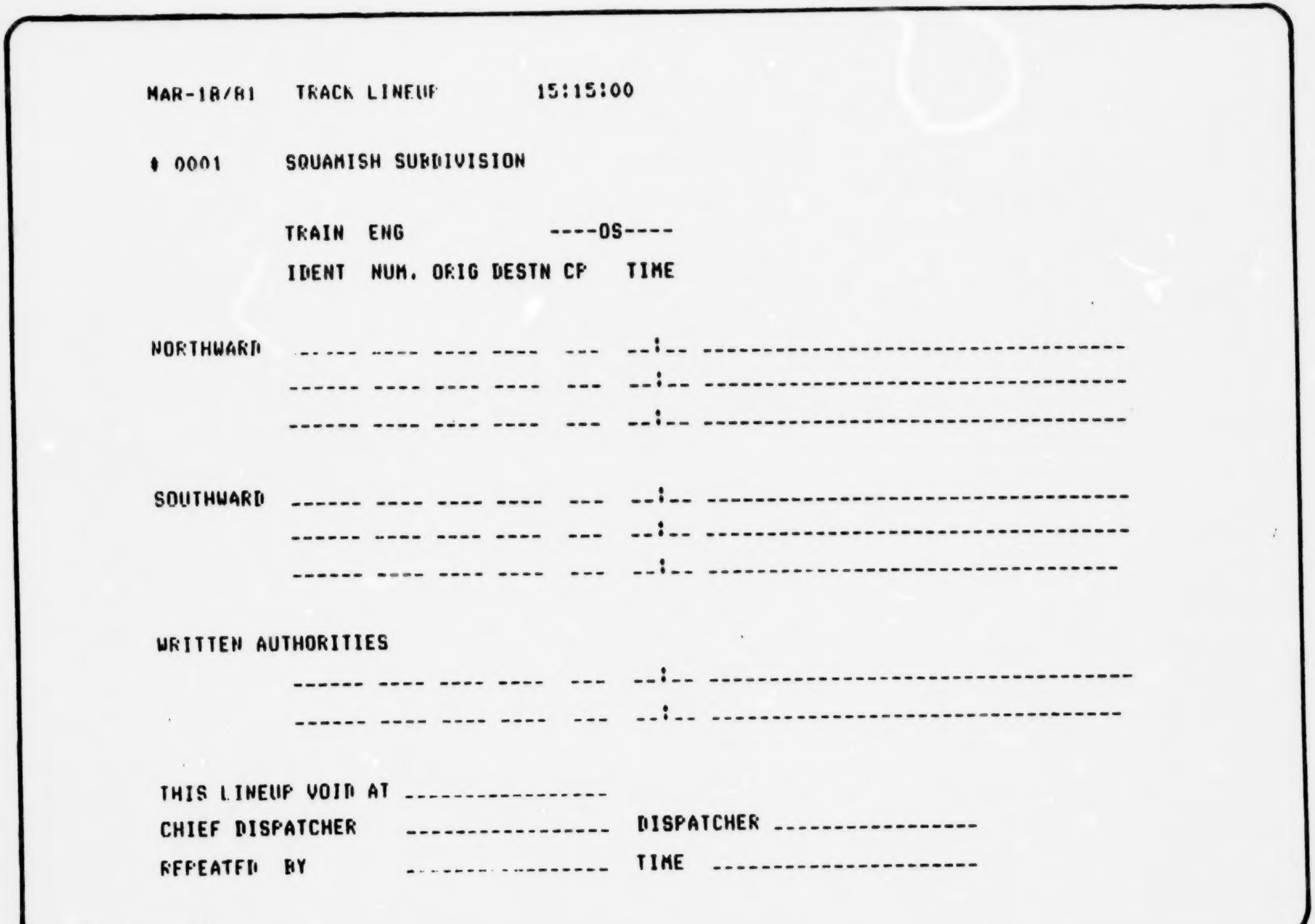
```
MAR-18/81                       15:24:31
             ARRIVAL DATA

TRAIN ------        STATUS ------------ CLASS -

ARRIVAL TIME  --:-- --/--    OFF DUTY TIME  --:-- --/--
CARS ARRIVING PSGR EQUIP --  LOADED ----  EMPTY ----  TOTAL -----

TONS ARRIVING ------

PASSENGER COUNT LEAVING ------   ARRIVING -----   TOTAL ------

DELAY REPORT:
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
```

FIGURE G-2 (e)



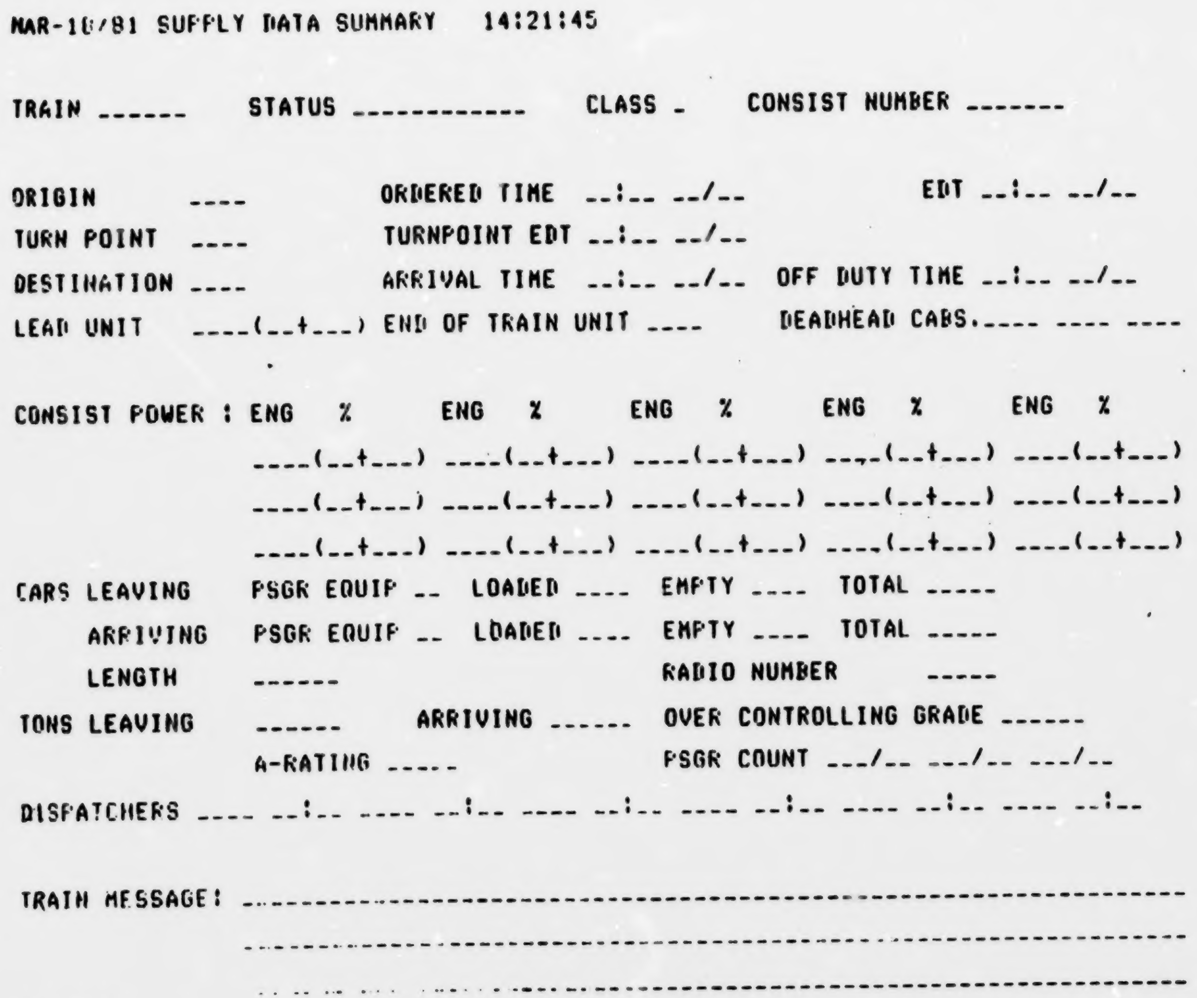
```
MAR-18/81   SUMMARY LINEUP      14:57:59

TRAIN  ENG                    ----OS---- STATUS
IDENT  NUM. TS FROM -TO-   CP  TIME  TYPE TIME  ENGINEMAN        CONDUCTOR
 NORTHBOUND
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
 SOUTHBOUND
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
------ ---- -  ---- ---- *--- --:--  --   --:-- ---------------- ---------------
 WRITTEN AUTHORITIES
------ ---- -  ---- ----
------ ---- -  ---- ----
------ ---- -  ---- ----
------ ---- -  ---- ----
------ ---- -  ---- ----
------ ---- -  ---- ----                                             MORE DATA
```

FIGURE G-3 (a)



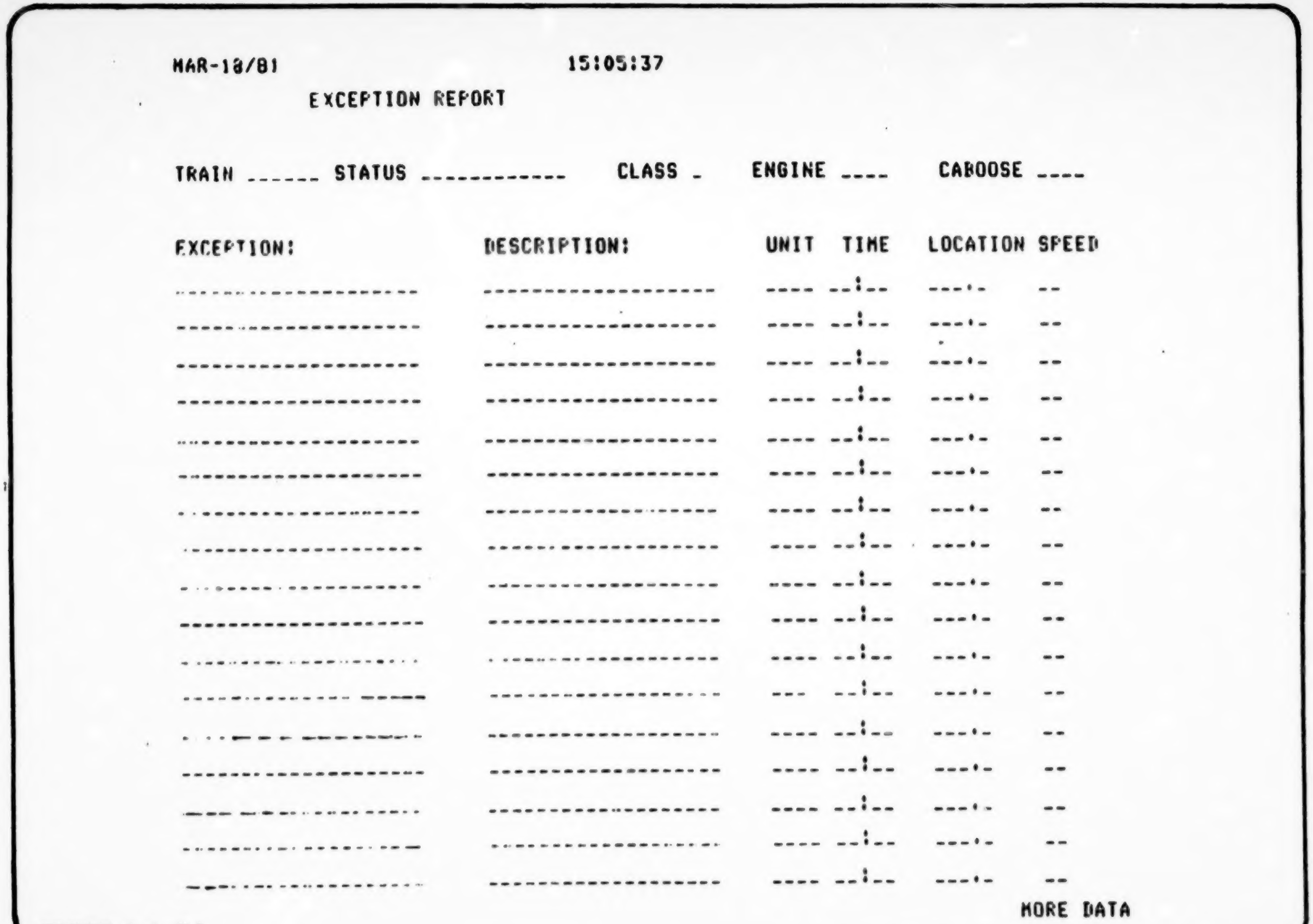
```
MAR-18/81   TRACK LINEUP        15:15:00

# 0001      SQUAMISH SUBDIVISION

            TRAIN  ENG             ----OS----
            IDENT  NUM. ORIG DESTN CP    TIME

NORTHWARD   ------ ---- ---- ----  ---  --:-- ----------------------------------
            ------ ---- ---- ----  ---  --:-- ----------------------------------
            ------ ---- ---- ----  ---  --:-- ----------------------------------

SOUTHWARD   ------ ---- ---- ----  ---  --:-- ----------------------------------
            ------ ---- ---- ----  ---  --:-- ----------------------------------
            ------ ---- ---- ----  ---  --:-- ---------------------------------

WRITTEN AUTHORITIES
            ------ ---- ---- ----  ---  --:-- ----------------------------------
            ------ ---- ---- ----  ---  --:-- ---------------------------------

THIS LINEUP VOID AT ----------------
CHIEF DISPATCHER    ----------------  DISPATCHER ----------------
REPEATED  BY        ----------------  TIME  ---------------------
```

FIGURE G-3 (b)



```
MAR-10/81 SUPPLY DATA SUMMARY   14:21:45

TRAIN ------    STATUS ------------    CLASS -    CONSIST NUMBER -------

ORIGIN        ----          ORDERED TIME  --:-- --/--             EDT --:-- --/--
TURN POINT    ----          TURNPOINT EDT --:-- --/--
DESTINATION   ----          ARRIVAL TIME  --:-- --/--  OFF DUTY TIME --:-- --/--
LEAD UNIT     ----(--+---) END OF TRAIN UNIT ----     DEADHEAD CABS.---- ---- ----

CONSIST POWER : ENG   %      ENG   %      ENG   %      ENG   %      ENG   %
                ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
                ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
                ----(--+---) ----(--+---) ----(--+---) ----(--+---) ----(--+---)
CARS LEAVING    PSGR EQUIP --  LOADED ----  EMPTY ----  TOTAL -----
     ARRIVING   PSGR EQUIP --  LOADED ----  EMPTY ----  TOTAL -----
     LENGTH     ------                      RADIO NUMBER      -----
TONS LEAVING    ------     ARRIVING ------  OVER CONTROLLING GRADE ------
                A-RATING -----              PSGR COUNT ---/-- ---/-- ---/--
DISPATCHERS ---- --:-- ---- --:-- ---- --:-- ---- --:-- ---- --:-- ---- --:--

TRAIN MESSAGE: ----------------------------------------------------------------
               ----------------------------------------------------------------
               ----------------------------------------------------------------
```

FIGURE G-4 (a)



```
MAR-18/81                          15:05:37
          EXCEPTION REPORT

TRAIN ______ STATUS ____________    CLASS _   ENGINE ____   CABOOSE ____

EXCEPTION:                DESCRIPTION:          UNIT  TIME   LOCATION SPEED
--------------------      ------------------    ---- --:--   ---.-     --
--------------------      ------------------    ---- --:--   ---.-     --
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--------------------      ------------------    ---- --:--   ---.-     --
--------------------      ------------------    ---- --:--   ---.-     --
--------------------      ------------------    ---- --:--   ---.-     --
                                                                MORE DATA
```
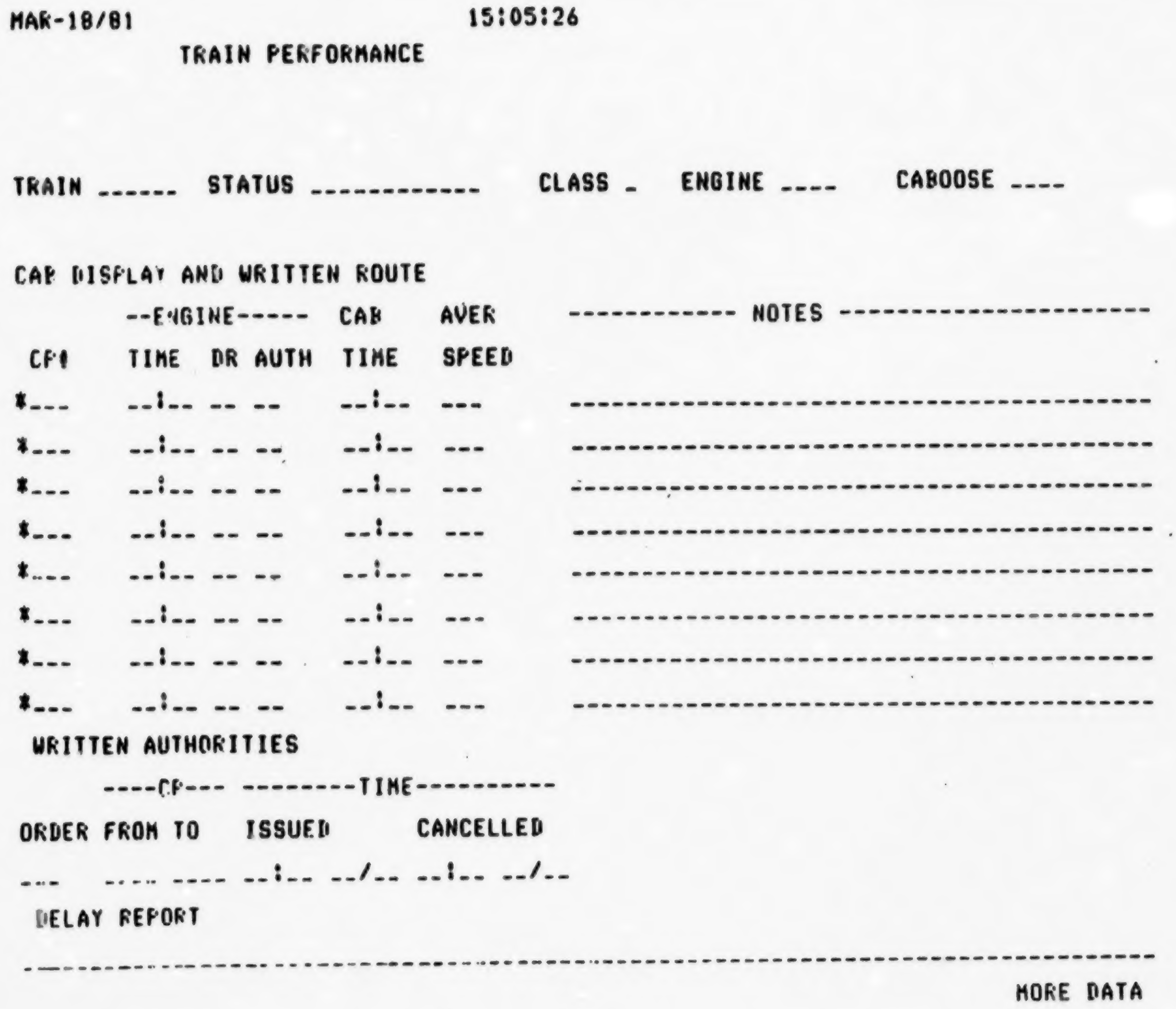
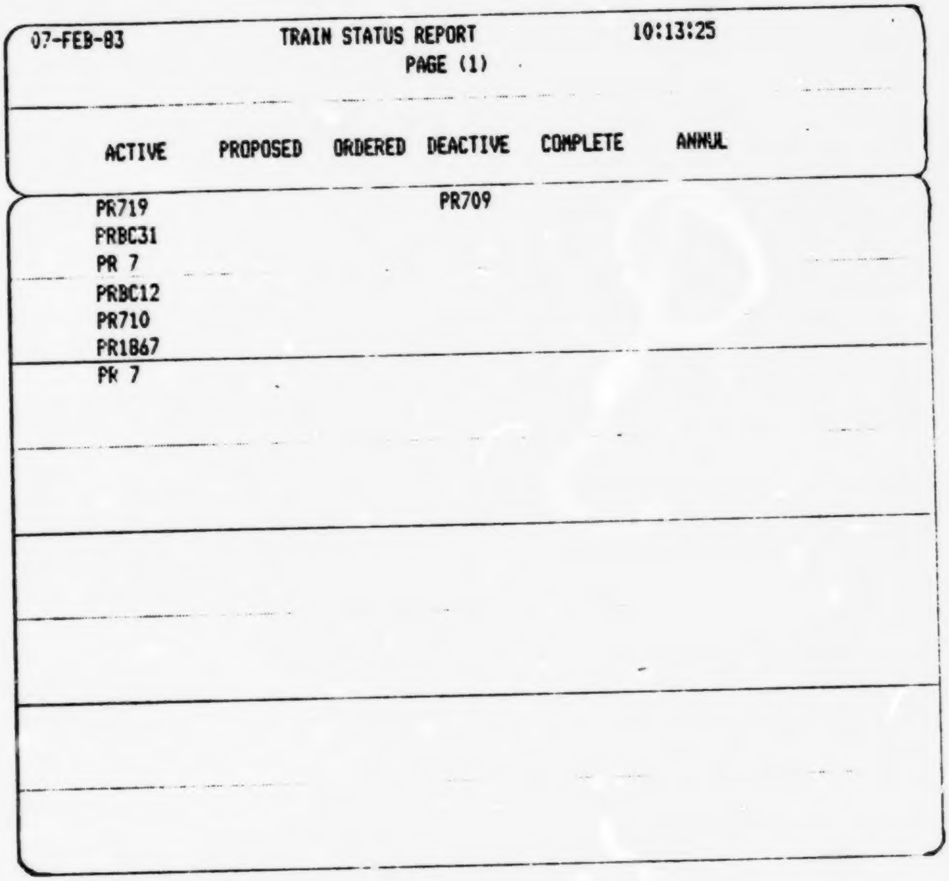

FIGURE G-4 (b)



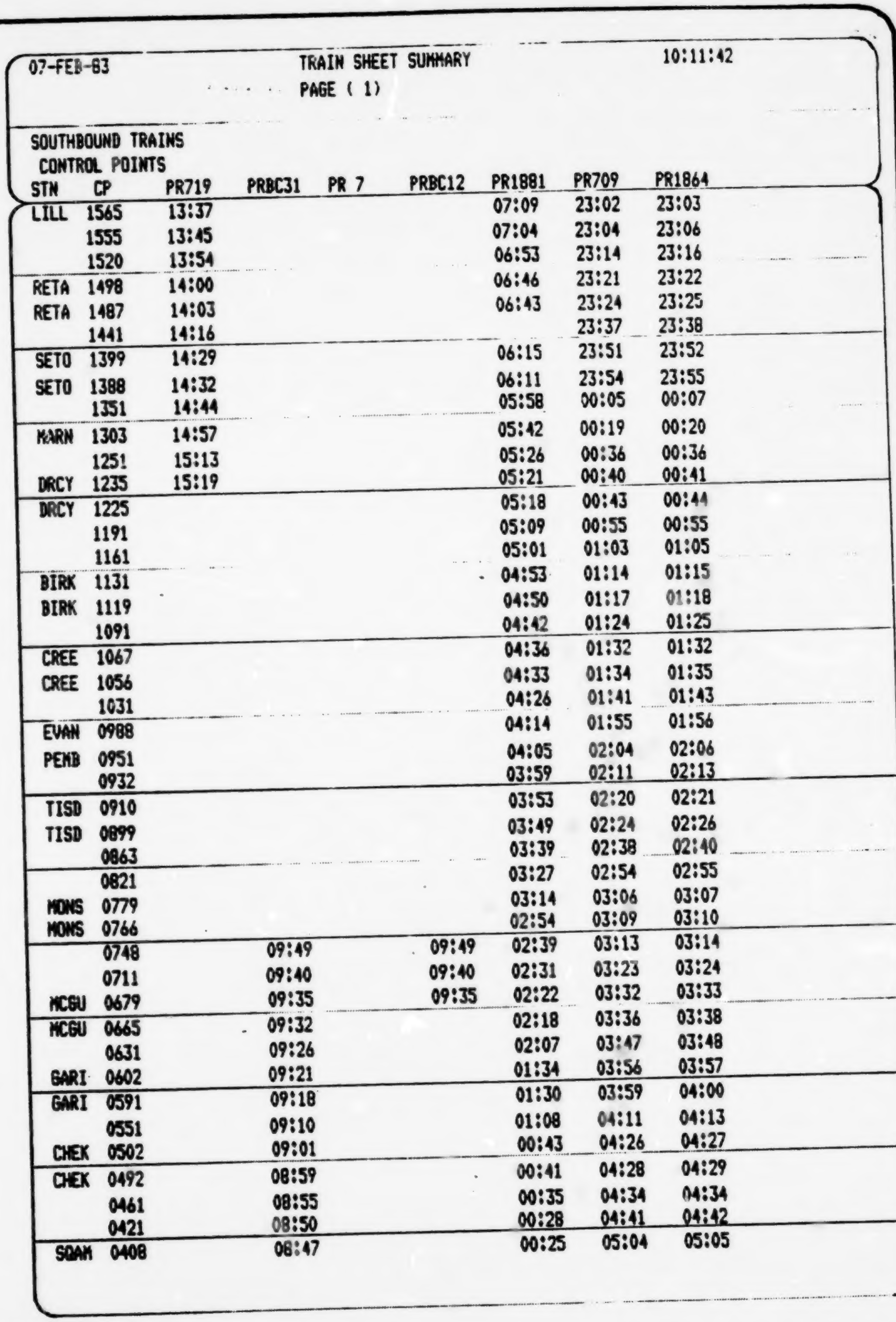
```
MAR-18/81                    15:05:26
          TRAIN PERFORMANCE


TRAIN ------ STATUS ------------    CLASS -  ENGINE ----    CABOOSE ----

CAB DISPLAY AND WRITTEN ROUTE
       --ENGINE-----  CAB    AVER     ------------ NOTES -----------------------
 CP#   TIME  DR AUTH  TIME   SPEED
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
*---   --:-- -- --    --:--  ---      ------------------------------------------
 WRITTEN AUTHORITIES
     ----CP--- --------TIME----------
ORDER FROM TO   ISSUED       CANCELLED
---   ---- ---- --:-- --/-- --:-- --/--
 DELAY REPORT
----------------------------------------------------------------------------
                                                                   MORE DATA
```

FIGURE G-4 (c)



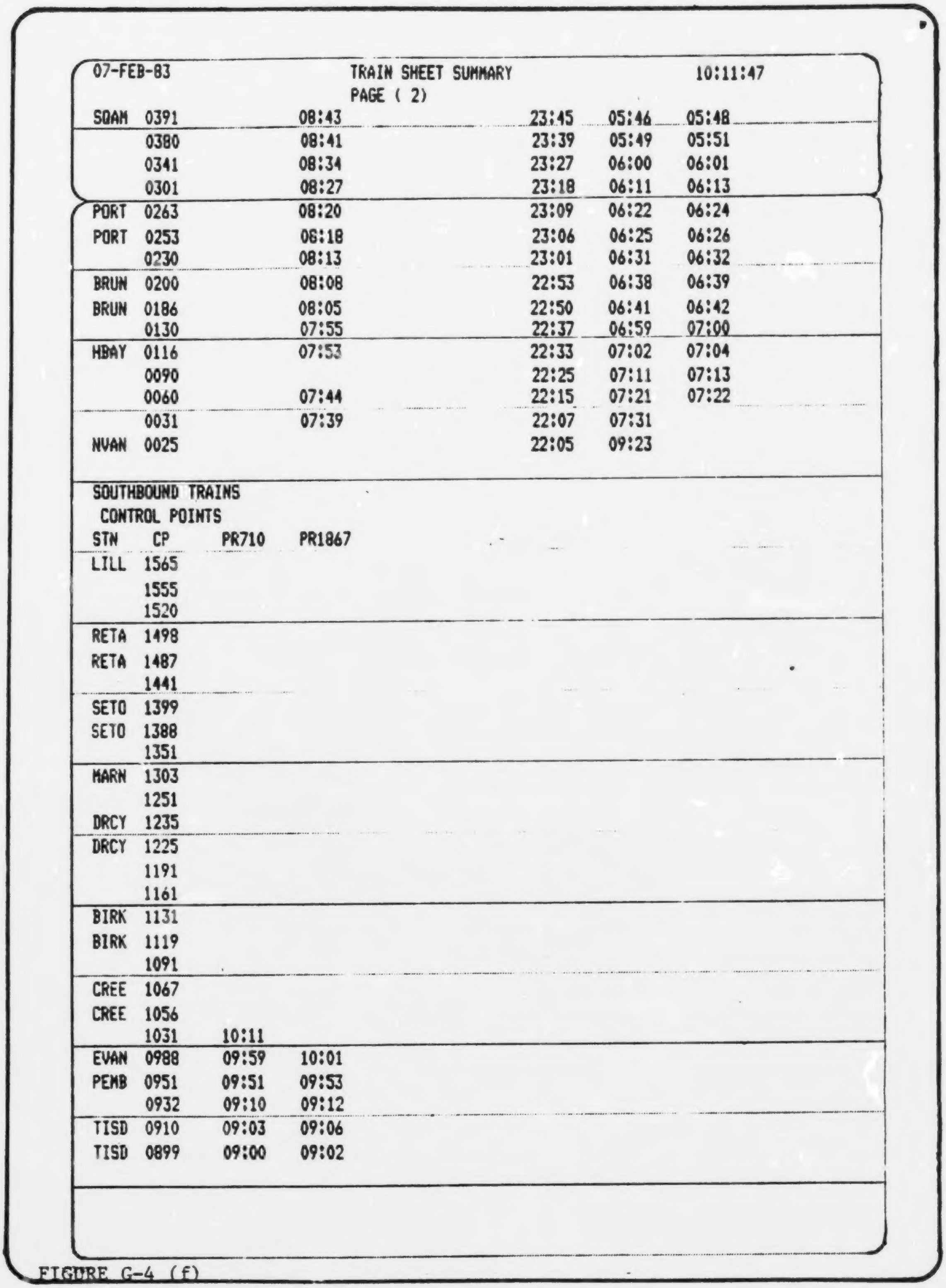
```
07-FEB-83                TRAIN STATUS REPORT              10:13:25
                                    PAGE (1)

      ACTIVE     PROPOSED   ORDERED  DEACTIVE  COMPLETE    ANNUL

      PR719                          PR709
      PRBC31
      PR 7
      PRBC12
      PR710
      PR1B67
      PR 7
```

FIGURE G-4 (d)



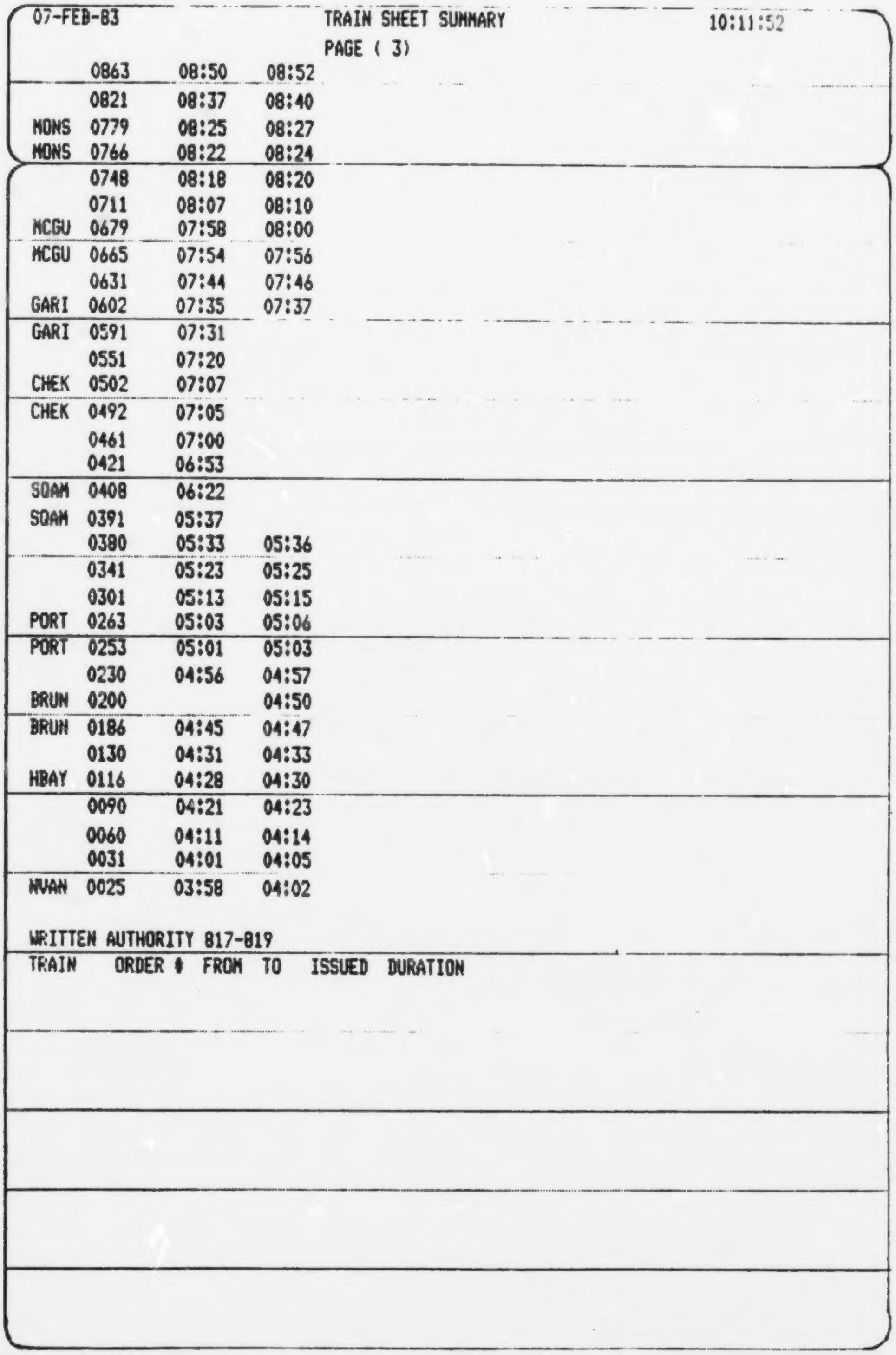
```
07-FEB-83                 TRAIN SHEET SUMMARY                   10:11:42
                          PAGE ( 1)

SOUTHBOUND TRAINS
 CONTROL POINTS
STN   CP     PR719   PRBC31   PR 7    PRBC12   PR1881   PR709   PR1864
LILL  1565   13:37                             07:09    23:02   23:03
      1555   13:45                             07:04    23:04   23:06
      1520   13:54                             06:53    23:14   23:16
RETA  1498   14:00                             06:46    23:21   23:22
RETA  1487   14:03                             06:43    23:24   23:25
      1441   14:16                                      23:37   23:38
SETO  1399   14:29                             06:15    23:51   23:52
SETO  1388   14:32                             06:11    23:54   23:55
      1351   14:44                             05:58    00:05   00:07
MARN  1303   14:57                             05:42    00:19   00:20
      1251   15:13                             05:26    00:36   00:36
DRCY  1235   15:19                             05:21    00:40   00:41
DRCY  1225                                     05:18    00:43   00:44
      1191                                     05:09    00:55   00:55
      1161                                     05:01    01:03   01:05
BIRK  1131                                     04:53    01:14   01:15
BIRK  1119                                     04:50    01:17   01:18
      1091                                     04:42    01:24   01:25
CREE  1067                                     04:36    01:32   01:32
CREE  1056                                     04:33    01:34   01:35
      1031                                     04:26    01:41   01:43
EVAN  0988                                     04:14    01:55   01:56
PEMB  0951                                     04:05    02:04   02:06
      0932                                     03:59    02:11   02:13
TISD  0910                                     03:53    02:20   02:21
TISD  0899                                     03:49    02:24   02:26
      0863                                     03:39    02:38   02:40
      0821                                     03:27    02:54   02:55
MONS  0779                                     03:14    03:06   03:07
MONS  0766                                     02:54    03:09   03:10
      0748           09:49            09:49    02:39    03:13   03:14
      0711           09:40            09:40    02:31    03:23   03:24
MCGU  0679           09:35            09:35    02:22    03:32   03:33
MCGU  0665           09:32                     02:18    03:36   03:38
      0631           09:26                     02:07    03:47   03:48
GARI  0602           09:21                     01:34    03:56   03:57
GARI  0591           09:18                     01:30    03:59   04:00
      0551           09:10                     01:08    04:11   04:13
CHEK  0502           09:01                     00:43    04:26   04:27
CHEK  0492           08:59                     00:41    04:28   04:29
      0461           08:55                     00:35    04:34   04:34
      0421           08:50                     00:28    04:41   04:42
SQAM  0408           08:47                     00:25    05:04   05:05
```

FIGURE G-4 (e)



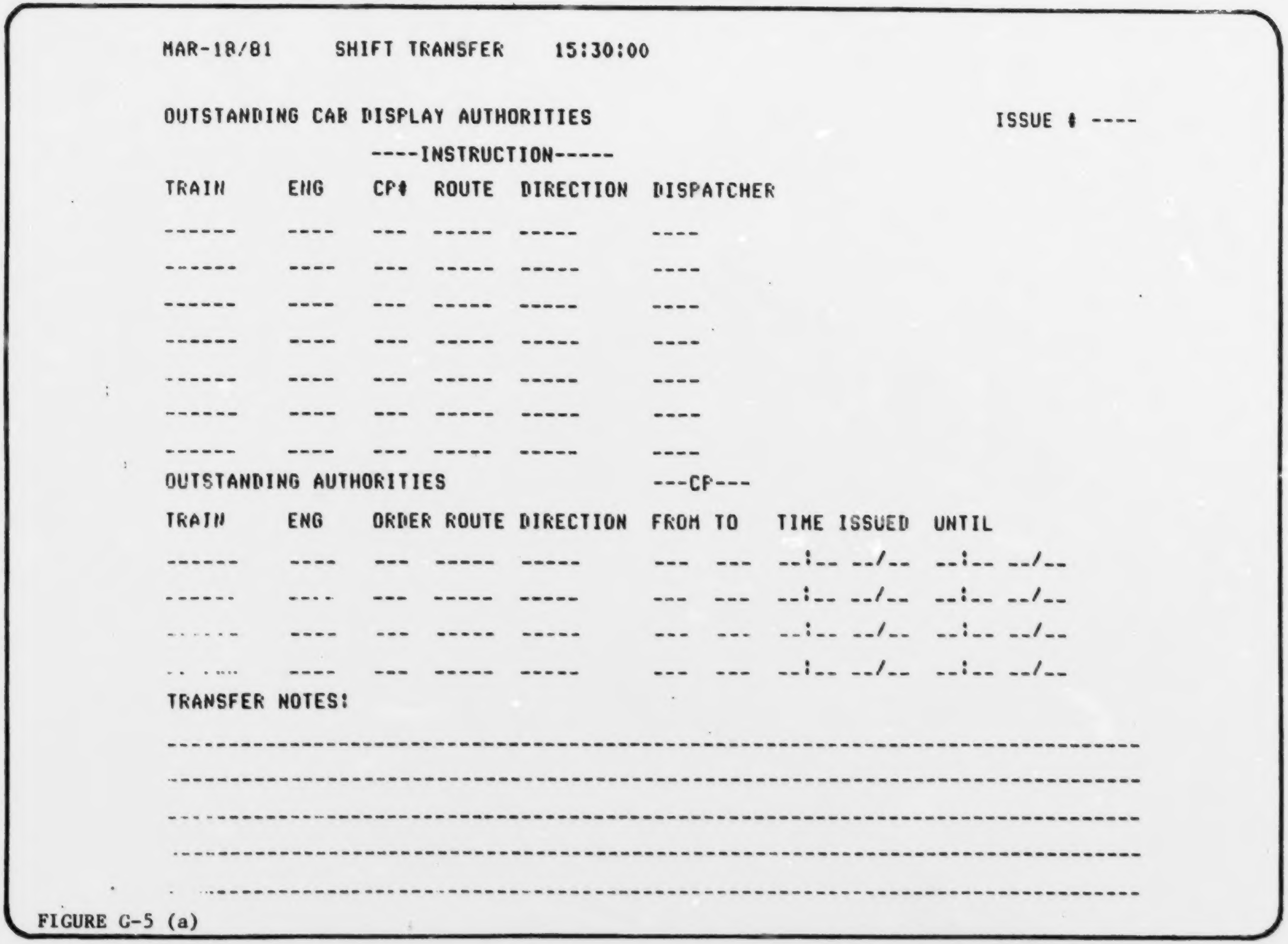
```
07-FEB-83                         TRAIN SHEET SUMMARY                         10:11:47
                                  PAGE ( 2)
SOAM  0391            08:43                        23:45   05:46   05:48
      0380            08:41                        23:39   05:49   05:51
      0341            08:34                        23:27   06:00   06:01
      0301            08:27                        23:18   06:11   06:13
PORT  0263            08:20                        23:09   06:22   06:24
PORT  0253            08:18                        23:06   06:25   06:26
      0230            08:13                        23:01   06:31   06:32
BRUN  0200            08:08                        22:53   06:38   06:39
BRUN  0186            08:05                        22:50   06:41   06:42
      0130            07:55                        22:37   06:59   07:00
HBAY  0116            07:53                        22:33   07:02   07:04
      0090                                         22:25   07:11   07:13
      0060            07:44                        22:15   07:21   07:22
      0031            07:39                        22:07   07:31
NVAN  0025                                         22:05   09:23

SOUTHBOUND TRAINS
 CONTROL POINTS
STN   CP     PR710    PR1867
LILL  1565
      1555
      1520
RETA  1498
RETA  1487
      1441
SETO  1399
SETO  1388
      1351
MARN  1303
      1251
DRCY  1235
DRCY  1225
      1191
      1161
BIRK  1131
BIRK  1119
      1091
CREE  1067
CREE  1056
      1031   10:11
EVAN  0988   09:59    10:01
PEMB  0951   09:51    09:53
      0932   09:10    09:12
TISD  0910   09:03    09:06
TISD  0899   09:00    09:02
```

FIGURE G-4 (f)



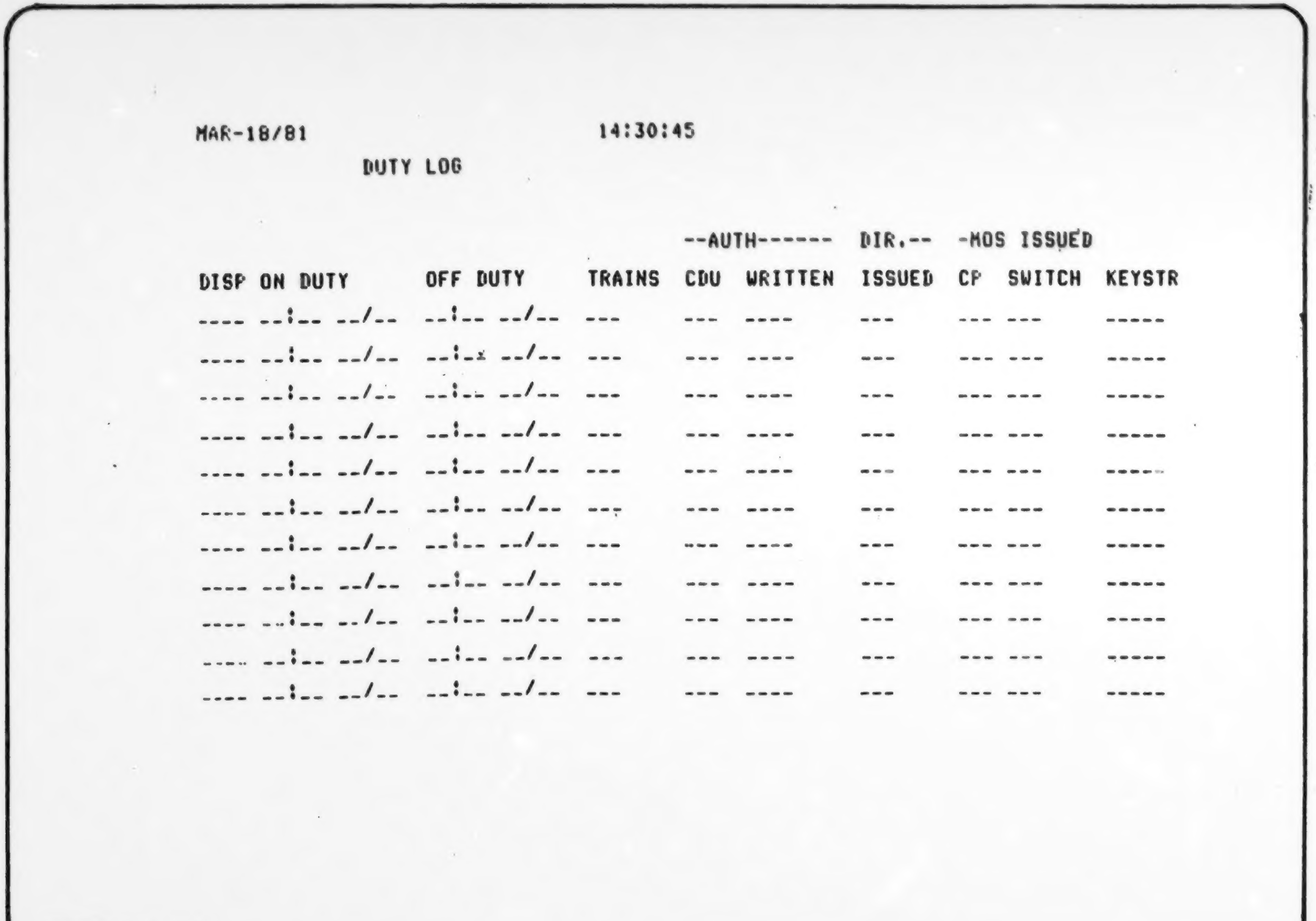
```
07-FEB-83                     TRAIN SHEET SUMMARY                  10:11:52
                              PAGE ( 3)
       0863    08:50    08:52
       0821    08:37    08:40
MONS   0779    08:25    08:27
MONS   0766    08:22    08:24
       0748    08:18    08:20
       0711    08:07    08:10
MCGU   0679    07:58    08:00
MCGU   0665    07:54    07:56
       0631    07:44    07:46
GARI   0602    07:35    07:37
GARI   0591    07:31
       0551    07:20
CHEK   0502    07:07
CHEK   0492    07:05
       0461    07:00
       0421    06:53
SQAM   0408    06:22
SQAM   0391    05:37
       0380    05:33    05:36
       0341    05:23    05:25
       0301    05:13    05:15
PORT   0263    05:03    05:06
PORT   0253    05:01    05:03
       0230    04:56    04:57
BRUN   0200             04:50
BRUN   0186    04:45    04:47
       0130    04:31    04:33
HBAY   0116    04:28    04:30
       0090    04:21    04:23
       0060    04:11    04:14
       0031    04:01    04:05
NVAN   0025    03:58    04:02

WRITTEN AUTHORITY 817-819
TRAIN    ORDER #  FROM  TO   ISSUED  DURATION
```

FIGURE G-4 (g)



```
MAR-18/81     SHIFT TRANSFER     15:30:00

OUTSTANDING CAB DISPLAY AUTHORITIES                                   ISSUE # ----
                    ----INSTRUCTION-----
TRAIN    ENG    CP#  ROUTE  DIRECTION  DISPATCHER
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
------   ----   ---  -----  -----      ----
OUTSTANDING AUTHORITIES                ---CP---
TRAIN    ENG    ORDER ROUTE DIRECTION  FROM TO   TIME ISSUED  UNTIL
------   ----   ---  -----  -----      ---  ---  --:-- --/--  --:-- --/--
------   ----   ---  -----  -----      ---  ---  --:-- --/--  --:-- --/--
------   ----   ---  -----  -----      ---  ---  --:-- --/--  --:-- --/--
------   ----   ---  -----  -----      ---  ---  --:-- --/--  --:-- --/--
TRANSFER NOTES:
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
```

FIGURE G-5 (a)



```
MAR-18/81                          14:30:45
               DUTY LOG

                                            --AUTH------ DIR.-- -MOS ISSUED
DISP ON DUTY        OFF DUTY     TRAINS CDU  WRITTEN  ISSUED CP  SWITCH  KEYSTR
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
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---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
---- --:-- --/--  --:-- --/--  ---    ---  ----     ---    --- ---     -----
```
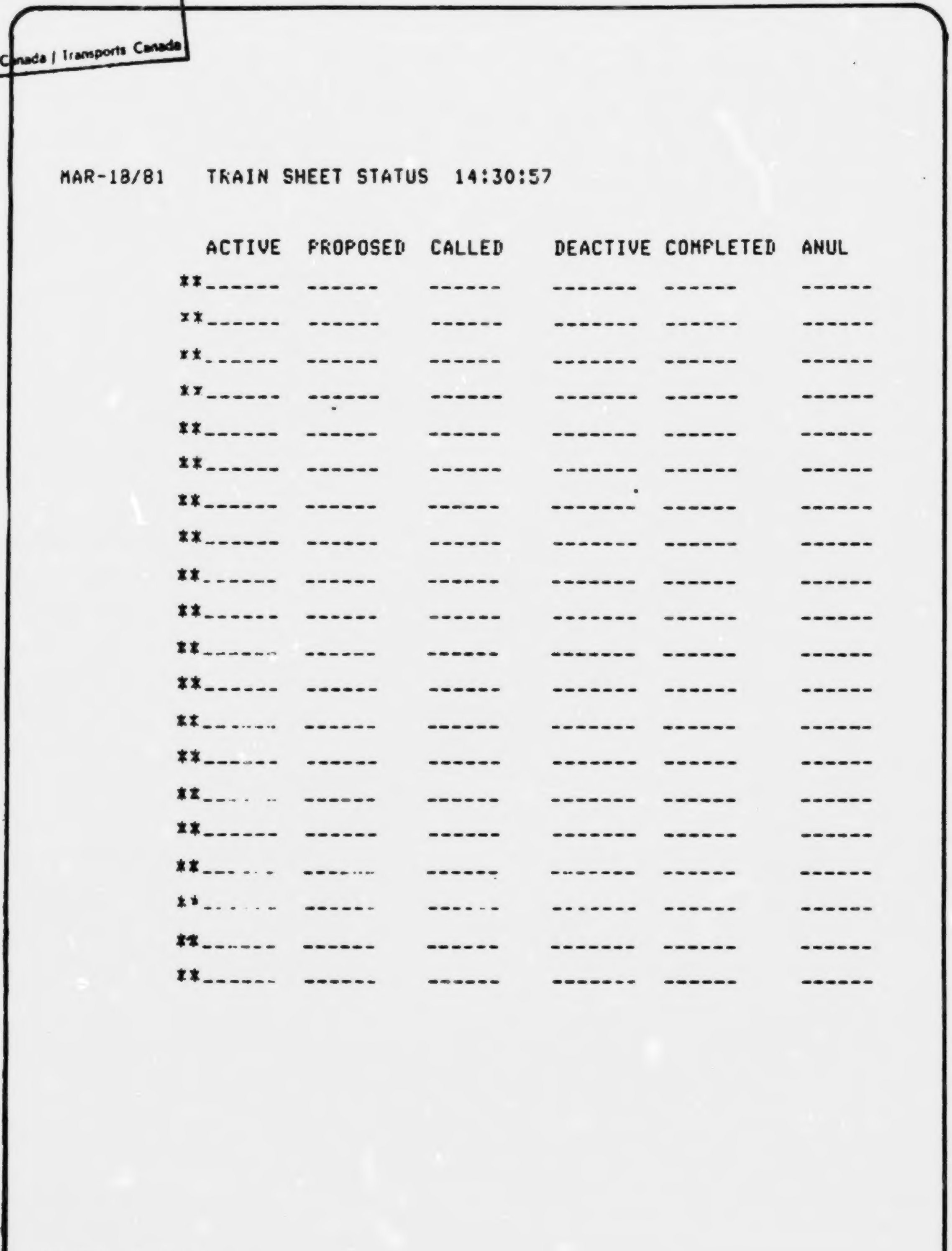

FIGURE G-5 (b)

ary and Information Centre /
Documentation (GSLA)
CU LE
DEC 2 1983
Transport Canada / Transports Canada



```
MAR-18/81   TRAIN SHEET STATUS  14:30:57

           ACTIVE  PROPOSED  CALLED    DEACTIVE COMPLETED  ANUL
         **------  ------    ------    -------  ------     ------
         **------  ------    ------    -------  ------     ------
         **------  ------    ------    -------  ------     ------
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         **------  ------    ------    -------  ------     ------
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         **------  ------    ------    -------  ------     ------
         **------  ------    ------    -------  ------     ------
         **------  ------    ------    -------  ------     ------
```

FIGURE G-5 (c)

POOR

QUALITY

ORIGINAL